



Calhoun: The NPS Institutional Archive
DSpace Repository

Theses and Dissertations

1. Thesis and Dissertation Collection, all items

1993-06

A feasibility study of expanding the F404 aircraft engine repair capability at the Aircraft Intermediate Maintenance Department

Bartlett, Stephen W., Sr.; Braun, Paul F.

Monterey, California. Naval Postgraduate School

<http://hdl.handle.net/10945/39768>

This publication is a work of the U.S. Government as defined in Title 17, United States Code, Section 101. Copyright protection is not available for this work in the United States.

Downloaded from NPS Archive: Calhoun



Calhoun is the Naval Postgraduate School's public access digital repository for research materials and institutional publications created by the NPS community. Calhoun is named for Professor of Mathematics Guy K. Calhoun, NPS's first appointed -- and published -- scholarly author.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

<http://www.nps.edu/library>

2

AD-A271 778



NAVAL POSTGRADUATE SCHOOL Monterey, California



DTIC
ELECTE
NOV 02 1993
S B D

THESIS

A FEASIBILITY STUDY OF EXPANDING THE F404
AIRCRAFT ENGINE REPAIR CAPABILITY AT THE
AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENT

by

Stephen W. Bartlett, Sr.
and
Paul F. Braun

June, 1993

Thesis Advisor:

Jeffery A. Warmington

Approved for public release; distribution is unlimited.

93 10 29 02 5

93-26293



Unclassified

Security Classification of this page

REPORT DOCUMENTATION PAGE

1a Report Security Classification: Unclassified			1b Restrictive Markings		
2a Security Classification Authority			3 Distribution/Availability of Report		
2b Declassification/Downgrading Schedule			Approved for public release; distribution is unlimited.		
4 Performing Organization Report Number(s)			5 Monitoring Organization Report Number(s)		
6a Name of Performing Organization Naval Postgraduate School		6b Office Symbol (if applicable) 36	7a Name of Monitoring Organization Naval Postgraduate School		
6c Address (city, state, and ZIP code) Monterey CA 93943-5000			7b Address (city, state, and ZIP code) Monterey CA 93943-5000		
8a Name of Funding/Sponsoring Organization		6b Office Symbol (if applicable)	9 Procurement Instrument Identification Number		
Address (city, state, and ZIP code)			10 Source of Funding Numbers		
			Program Element No	Project No	Task No
			Work Unit Accession No		
11 Title (include security classification) A FEASIBILITY STUDY OF EXPANDING THE F404 AIRCRAFT ENGINE REPAIR CAPABILITY AT THE AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENT					
12 Personal Author(s) Bartlett, Sr., Stephen W. and Braun, Paul F.					
13a Type of Report Master's Thesis		13b Time Covered From To	14 Date of Report (year, month, day) June 1993		15 Page Count 212
16 Supplementary Notation The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.					
17 Cosati Codes			18 Subject Terms (continue on reverse if necessary and identify by block number)		
Field	Group	Subgroup	Turbofan Engine Maintenance, Expansion of Maintenance Capabilities, Simulation Modeling, F404-GE-400/402 Engine, Intermediate Maintenance, Aircraft Intermediate Maintenance Department, AIMD		
19 Abstract (continue on reverse if necessary and identify by block number)					
<p>This thesis provides a feasibility study and cost analysis to determine what generic engine depot level capabilities should be shifted to "selected" Aircraft Intermediate Maintenance Departments (AIMD) to reduce costs and improve fleet support of F404-GE-400/402 turbofan engines. The downsizing of the military in the next decade, the resulting budget constraints and the reality of base closures will force the Navy to adopt innovative cost saving measures. This thesis used simulation modeling of the F404 engine repair process at AIMDs Cecil Field and Lemoore to evaluate the feasibility of expanding repair capabilities. The simulation model outcomes provided strong indications that such expansion of the AIMDs is both feasible and cost effective. The researchers recommend shifting selected depot repair capabilities to the AIMD. Recommendations include positioning a spin-balance machine and increasing the welding repair capability at "selected" AIMDs to reduce BCM actions, turn-around times and repair costs for the F404 aircraft engine.</p>					
20 Distribution/Availability of Abstract XXX unclassified/unlimited same as report DTIC users			21 Abstract Security Classification Unclassified		
22a Name of Responsible Individual Jeffery A. Warmington			22b Telephone (include Area Code) (408) 656-2966		22c Office Symbol AS/Wr

DD FORM 1473,84 MAR

83 APR edition may be used until exhausted

All other editions are obsolete

security classification of this page

Unclassified

Approved for public release; distribution is unlimited.

A Feasibility Study of Expanding the F404
Aircraft Engine Repair Capability at the
Aircraft Intermediate Maintenance Department

by

Stephen W. Bartlett, Sr.

Lieutenant Commander, United States Navy

B.S., Georgia State University, 1978

and

Paul F. Braun

Lieutenant Commander, United States Navy

B.S., Northern State College, 1976

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL

June 1993

Authors:

Stephen W. Bartlett, Sr.

Paul F. Braun

Approved by:

Jeffery A. Warmington, Principal Thesis Advisor

Alan W. McMasters, Associate Thesis Advisor

David R. Whipple, Chairman
Department of Administrative Sciences

ABSTRACT

This thesis provides a feasibility study and cost analysis to determine what generic engine depot level capabilities should be shifted to "selected" Aircraft Intermediate Maintenance Departments (AIMD) to reduce costs and improve fleet support of F404-GE-400/402 turbofan engines. The downsizing of the military in the next decade, the resulting budget constraints and the reality of base closures will force the Navy to adopt innovative cost saving measures. This thesis used simulation modeling of the F404 engine repair process at AIMDs Cecil Field and Lemoore to evaluate the feasibility of expanding repair capabilities. The simulation model outcomes provided strong indications that such expansion of the AIMDs is both feasible and cost effective. The researchers recommend shifting selected depot repair capabilities to the AIMD. Recommendations include positioning a spin-balance machine and increasing the welding repair capability at "selected" AIMDs to reduce BCM actions, turn-around times and repair costs for the F404 aircraft engine.

DTIC QUALITY INSPECTED 8

Accession For	
NTIS GRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

TABLE OF CONTENTS

I.	INTRODUCTION	1
A.	OBJECTIVES	1
B.	HISTORY	2
C.	THESIS OBJECTIVE	7
D.	SCOPE	8
E.	PREVIEW	9
II.	BACKGROUND	10
A.	THE NAVAL AVIATION MAINTENANCE PROGRAM	10
1.	Levels of Maintenance	11
a.	Organizational Level Maintenance	12
b.	Intermediate Level Maintenance	13
c.	Depot Level Maintenance	14
B.	AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENT	15
1.	Organization	16
a.	Maintenance/Material Control	
	(Production)	17
b.	Quality Assurance/Analysis	18
c.	Production Control	18
d.	Material Control	19
e.	Power Plants Division	19
	(1) Third Degree Repair	20

(2) Second Degree Repair.	20
(3) First Degree Repair.	21
(4) Repair Beyond First Degree.	21
(5) Manning and Training.	22
C. AIMD NAS CECIL FIELD	23
D. AIMD NAS LEMOORE	25
E. F404-GE-400/402 ENGINE	27
1. Background	27
2. Engine Characteristics	28
a. Fan Module	30
b. High Pressure Compressor Module	30
c. Combustor Module	30
d. High Pressure Turbine Module	30
e. Low Pressure Turbine Module	31
f. Afterburner Module	31
3. F404 Reliability and Maintenance	32
a. Reliability	32
b. Maintenance	33
F. FUNDING SHORTFALLS	35
1. Background	35
2. Current Funding Outlook	35
III. AIMD MAINTENANCE CAPABILITIES/LIMITATIONS REVIEW	38
A. F404 MAINTENANCE PLAN REVIEW	38
1. Fan Module	41
a. Current AIMD Capabilities	41

b.	Current AIMD Limitations	41
2.	High Pressure Compressor Module	42
a.	Current AIMD Capabilities	42
b.	Current AIMD Limitations	43
3.	Combustor Module	43
a.	Current AIMD Capabilities	43
b.	Current AIMD Limitations	44
4.	High Pressure Turbine Module	44
a.	Current AIMD Capabilities	44
b.	Current AIMD Limitations	45
5.	Low Pressure Turbine Module	45
a.	Current AIMD Capabilities	45
b.	Current AIMD Limitations	46
6.	Afterburner Module	46
a.	Current AIMD Capabilities	46
b.	Current AIMD Limitations	47
B.	CURRENT MAINTENANCE PROCEDURES	47
C.	EXPANDED AIMD REPAIR CAPABILITIES	50
1.	Spin Balancing Capability	51
a.	Spin Balancing Machine	51
b.	Personnel, Training, and Maintenance Requirements	53
2.	Welding Capability	54
3.	Blade Tip Grinding and Balancing Capability	55
a.	Blade Tip Grinding and Balancing Machine	56

b.	Personnel, Training, and Maintenance Requirements	57
IV.	SIMULATION MODEL DEVELOPMENT	59
A.	QUEUEING THEORY	60
B.	HYPOTHESIS	60
1.	Hypothesis Statement	61
2.	Approach	61
C.	OVERVIEW OF SIMULATION	62
1.	Description of SIMAN	63
a.	Model Frame	63
b.	Experiment Frame	64
2.	Description of Probability Distributions	65
D.	ASSUMPTIONS USED IN THE SIMAN SIMULATION MODELS	72
E.	INFORMATION COLLECTION	74
F.	PARAMETERS FOR AIMD SIMULATION MODELS	75
1.	Interarrival Times	76
2.	Service Times	76
3.	Engine and Module Repair Channels	79
4.	BCM Rates for Engine and Modules	81
5.	Awaiting Parts Time and Average Customer Wait Time	82
6.	Engine and Module Spares	83
7.	Module Failure Percentages	83
G.	AIMD SIMULATION MODELS	84
1.	Current AIMD F404 Power Plant Model	85

2. Proposed "Selected" AIMD Power Plant Model	91
V. ANALYSIS OF MODEL RESULTS	94
A. MODEL VALIDATION	94
1. AWP Model Validation	96
2. WIP Model Validation	97
3. Items Repaired	98
4. BCM Actions	99
B. ANALYSIS OF CURRENT CAPABILITIES VERSUS EXPANDED CAPABILITIES	101
1. Comparison of TAT, WIP, AWP and AWM	101
2. Comparison of Items Processed/Repaired and the Effects on BCM Rates	105
3. Comparison of Work Center Utilization between Current and Expanded Simulation Models	107
4. Comparison of Spare Utilization	110
C. PROJECTED COST SAVINGS RESULTING FROM EXPANDED CAPABILITIES	111
D. ANALYSIS OF INCREASED THROUGHPUT AND EFFECTS ON TAT AND WORK CENTER UTILIZATION	114
VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	117
A. SUMMARY	117
B. CONCLUSIONS	118
C. RECOMMENDATIONS	121

LIST OF REFERENCES	123
APPENDIX A	126
APPENDIX B	136
APPENDIX C	138
APPENDIX D	170
APPENDIX E	178
APPENDIX F	194
INITIAL DISTRIBUTION LIST	196

LIST OF TABLES

TABLE 2.1 - AIMD CECIL FIELD TEST CELLS	25
TABLE 2.2 - AIMD LEMOORE TEST CELLS	26
TABLE 2.3 - F404-GE-400/402 ENGINE CHARACTERISTICS .	29
TABLE 2.4 - FLEET EXPERIENCE WITH F404 AND OTHER ENGINES	32
TABLE 2.5 - FY 93 COMPONENT REPAIR FUNDING SUMMARY (\$ M)	36
TABLE 2.6 - FY 93 F404 ENGINE/MODULE FUNDING SUMMARY (\$000)	36
TABLE 2.7 - FY 93 FUNDING SUMMARY(\$000) LIFE LIMIT REDUCTIONS	37
TABLE 4.1 - AVG. ENGINE ARRIVAL/MO. & INTERARRIVAL TIMES	76
TABLE 4.2 - AIMD CECIL FIELD SERVICE TIMES(HRS)	77
TABLE 4.3 - AIMD LEMOORE SERVICE TIMES (HRS)	78
TABLE 4.4 - SIMAN MODEL REPAIR CHANNELS	81
TABLE 4.5 - ENGINE AND MODULE BCM RATES	81
TABLE 4.6 - AWAITING PARTS (AWP) AND AVERAGE CUSTOMER WAIT TIME (ACWT) (HRS)	82
TABLE 4.7 - ENGINE AND MODULE RFI SPARE ALLOWANCES . .	83
TABLE 4.8 - MODULE FAILURES (PERCENT OF ENGINE INDUCTIONS)	84

TABLE 5.1-COMPARISON OF AWP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD	97
TABLE 5.2-COMPARISON OF AWP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE (HRS)	97
TABLE 5.3-COMPARISON OF WIP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD (HRS)	98
TABLE 5.4-COMPARISON OF WIP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE (HRS)	98
TABLE 5.5-COMPARISON OF ITEMS PROCESSED/REPAIRED USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD	99
TABLE 5.6-COMPARISON OF ITEMS PROCESSED/REPAIRED USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE	99
TABLE 5.7-COMPARISON OF BCM ACTIONS USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD	100
TABLE 5.8-COMPARISON OF BCM ACTIONS USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE	100
TABLE 5.9-AIMD CECIL FIELD COMPARISON OF TAT, WIP, AWP AND AWM (HRS)	103

TABLE 5.10-AIMD LEMOORE COMPARISON OF TAT, WIP, AWP AND AWM (HRS)	104
TABLE 5.11-COMPARISON OF NUMBER OF ITEMS REPAIRED AND BCM ACTIONS FOR AIMD CECIL FIELD	106
TABLE 5.12-COMPARISON OF NUMBER OF ITEMS REPAIRED AND BCM ACTIONS FOR AIMD LEMOORE	106
TABLE 5.13-COMPARISON OF FY-92 NALDA BCM RATES WITH EXPANDED MODEL BCM RATES FOR AIMDs CECIL FIELD AND LEMOORE	107
TABLE 5.14-PROJECTED NUMBER OF MODULES SPIN BALANCED AT THE AIMDs	107
TABLE 5.15-COMPARISON OF WORK CENTER UTILIZATION RATES FROM SIMULATION MODELS (AVERAGE PERCENT)	108
TABLE 5.16-COMPARISON OF AVERAGE SPARE ENGINE/MODULE UTILIZATION (UNITS)	110
TABLE 5.17-COMPARISON OF WORK CENTER UTILIZATION WHEN PROCESSING 400 ENGINES PER YEAR AT "SELECTED" AIMDs	114
TABLE 5.18-COMPARISON OF TAT, AWP, AND WIP WHEN PROCESSING 400 ENGINES PER YEAR AT "SELECTED" AIMDs (HRS)	116

LIST OF FIGURES

Figure 2.1 - AIMD Organizational Chart (Ashore).	17
Figure 2.2 - AIMD Cecil Field's Power Plants Division Organization and Manning.	24
Figure 2.3 - AIMD Lemoore's Power Plants Division Organization and Manning.	26
Figure 4.1 - Poisson Distribution.	67
Figure 4.2 - Exponential Distribution.	68
Figure 4.3 - Normal Distribution.	69
Figure 4.4 - Triangular Distribution.	70
Figure 4.5 - Log Normal Distribution.	71
Figure 4.6 - SIMAN Block Diagram.	86

ACKNOWLEDGEMENTS

The researchers wish to express their appreciation to Commander Jeffery A. Warmington and Professors Keebom Kang and Alan W. McMasters of the Department of Administrative Sciences, Naval Postgraduate School, Monterey, California. Their insight and guidance were major factors in the writing of this report.

The researchers also wish to express their gratitude to Professor Kang for his special class in the use of the SIMAN simulation language and his advice and counsel in developing our simulation models.

I. INTRODUCTION

A. OBJECTIVES

The Navy currently has one Naval Aviation Depot¹ (NADEP), Jacksonville (JAX), Florida, which completes maintenance and repair actions on the F/A-18 aircraft engine (F404-GE-400/402) and modules². There are also 26 intermediate level repair facilities which support the F/A-18 aircraft. Of these, only six can provide first degree³ repair capability. These six facilities are located at NAS Cecil Field, NAS Lemoore, Naval Station (NAVSTA) Rota, Marine Aviation Logistics Squadron (MALS)-31, MALS-11, and MALS-12. [Ref. 1:Encl. (18)]

This study will focus on the feasibility of transferring selected "high payback" depot level functions from NADEP JAX to the Aircraft Intermediate Maintenance Departments (AIMD's) at NAS Cecil Field and NAS Lemoore. As used in this thesis "high payback" is defined as a function that has a high total

¹ The three maintenance levels are organizational ("O" level), intermediate ("I" level), and depot ("D" level).

² The F404-GE-400/402 engines are modular in construction. Six modules make up an engine. These modules are the Fan, High Pressure Compressor (HPC), Combuster, High Pressure Turbine (HPT), Low Pressure Turbine (LPT), and Afterburner.

³ Intermediate level repair facilities are classified by degree of repair capability. The three classifications are first, second or third degree repair capability, with first degree being the most capable.

dollar value and that has a direct impact on aircraft readiness.

The Navy continuously reviews and revises aviation maintenance policy and practices to optimize the capabilities of the three maintenance levels. The pressure of reduced depot maintenance funding coupled with the potential for NADEP closure as a result of Base Realignment and Closure (BRAC) studies are a concern with respect to depot repair of jet engines. An alternative to reduced rework due to depot funding cuts or depot engine facility closure is the transfer of selected depot capabilities to "selected" shorebased Aircraft Intermediate Maintenance Department (AIMD) facilities. This thesis will use the F404 engine as a basis for studying the impact of expanding engine maintenance and repair capabilities at "selected" AIMD's. The impact will be analyzed in terms of the effect on work in process (WIP) inventories, turn around time (TAT), capacity utilization, and any additional manpower requirements at the "selected" AIMD's.

B. HISTORY

Until late 1991 both NADEP JAX and NADEP North Island (NORIS), California, were depot repair sites for the F404 engine. [Ref. 1:Encl (18)] NADEP JAX then became the only depot repair site for the F404 engine as a result of Defense Management Review Decision (DMRD) 908. [Ref. 2] This Defense Management Review (DMR) was conducted by the Secretary of

Defense (SECDEF) in June 1989 to present a plan to the President that would:

1. implement fully the recommendations of the Packard Commission⁴,
2. improve substantially the performance of the defense acquisition system; and
3. manage more effectively the DoD and defense resources.
[Ref. 2]

According to DMRD 908, DoD should consolidate the Army, Navy, and Air Force aeronautical depot maintenance into a single defense-wide entity in an effort to more effectively manage DoD organic industrial resources. DMRD 908 recommended that:

Since the Air Force has a majority of aeronautical depot maintenance, they would be the logical choice as manager of the consolidated function. All resources associated with the performance of organic aeronautical depot level maintenance should be placed under this manager. A single manager should streamline the management of DoD organic industrial resources. Each military department would still be responsible for determining its depot maintenance requirements and budgeting for depot maintenance support.
[Ref. 2]

DMRD 908 concluded that the recommended consolidation "...should result in the closure of two of twelve organic aeronautical depots." [Ref. 2]

⁴ The Packard Commission - The commission made clear that Americans think inefficiency in DoD spending to be a problem of major proportions. The commission concluded the defense acquisition process was not operated or managed effectively, and this was having disastrous effects on the cost and efficiency of the DoD acquisition process.

After review of the original DMRD 908, Deputy Secretary of Defense Atwood decided to hold DMRD 908 in abeyance. He directed the Secretaries of the Military Departments to take specific actions designed to achieve the objectives of the DMRD without implementing the "single manager" concept. Deputy Secretary of Defense Atwood concluded that "...substantial opportunities exist to increase the efficiency and reduce the cost of the Department's depot maintenance operations, while ensuring that they continue to conduct effectively their crucial maintenance mission." [Ref. 3:p. 1]

Specifically in the area of aviation depot level maintenance, the Secretary of the Navy was directed by Atwood to ensure that:

1. the naval aviation depot maintenance structure is streamlined so as to establish one aviation depot maintenance hub⁵ on the east coast of the United States and one on the west coast;
2. all non-hub aviation depot maintenance facilities are reduced in size and perform technology-specific maintenance, or are closed, as appropriate;
3. the workload of all naval aviation depot maintenance of a particular type of aircraft is performed at a single

⁵ Naval Depot Hubs - The depot hubs are major industrial support centers. The hub complexes are located at Naval Air Station Norfolk, Virginia and Naval Air Station North Island, California. They provide engineering, logistic, and maintenance support to the operating fleet. The hub consists of a Business Operating Center, which contains employees performing consolidated corporate business overhead functions, and a Depot Production Center which provides technology- and commodity-focussed manufacturing, rework and overhaul services in support of assigned weapon systems.

site, to reduce the number of product lines at a given depot;

4. engine depot maintenance is performed at no more than three depots; and

5. other maintenance workloads of the Department of the Navy are consolidated as appropriate. [Ref. 3:pp. 1-2]

As a result of this direction, the Naval Air Systems Command (NAVAIR) convened a meeting of the Naval Aviation Depot Corporate Board. This team studied over 50 separate consolidation options to determine which combinations of workload restructuring and streamlining opportunities would provide the most cost reductions, meet the objectives of DMRD 908, and maintain high levels of fleet readiness. The team produced the new Naval Aviation Depot Corporate Business Plan which was approved by the Under Secretary of the Navy in February, 1991. NADEP JAX was approved as the depot facility for maintaining and repairing the F404 engine and modules in the Corporate Business Plan. [Ref. 4]

In his 1993 State of the Union Address, President Bill Clinton announced that the Department of Defense budget would be reduced by \$76 billion over the next four years. [Ref. 5] He also announced many new domestic Federal programs which will place additional burdens on the growing national deficit. With the Cold War over, many people now expect the Department of Defense to provide the peace dividend for funding of other domestic programs. It is not uncommon for members of the

House of Representatives or Senate to propose new programs which will be funded from savings in the defense budget.

The Navy recognizes the need to plan for these political and budget realities and is continuously trying to simplify processes, perform required tasks more efficiently, and determine the level at which maintenance and repair can be performed in the most cost effective manner. This enables the Navy to make the best utilization of scarce funding resources while maintaining readiness.

The Chief of Naval Operations (CNO) sponsors and directs the Naval Aviation and Maintenance Program (NAMP). The six volume OPNAVINST 4790.2E series sets forth the CNO's objectives, doctrine and policies for Naval Aviation Maintenance. Navy aircraft maintenance support at the intermediate level is typically provided by either the AIMD at the Naval Air Station (NAS) or on the aircraft carrier (CV) at which the aircraft are based. Those repairs which are not authorized to be performed by the AIMD or are beyond the capability of maintenance (BCM) for whatever reason are then sent to the depot level for repair. Depot level repairs are normally more complex and expensive than intermediate level repairs. [Ref. 6] This policy, which on the whole has seemed to be a successful way to provide maintenance support at this level, may not be the most cost-effective.

In response to reduced funding levels and potential closure of a NADEP resulting from its inclusion on the BRAC

list which will be forwarded to the President in July, 1993, alternatives for engine maintenance and repair actions now performed at that NADEP are being considered. One option to offset reduced engine rework due to funding cuts or depot engine facility closure is to transfer the "high payback" depot functions to "selected" shore-based AIMD activities. These are not the only reasons the Navy prefers to do repairs at the I-level. In the study, "Depot Maintenance of Aviation Components: Contractor vs. Organic Repair", Embry stated that:

There are both operational and economic reasons for the services' preference for extensive I-level capabilities. For example, the services must be prepared to conduct operations worldwide, and in locations where there are no established resupply channels. In addition, since failed components that cannot be repaired by I-level incur long pipeline delays, I-level investments may be economically viable. Shortening these pipelines could make a two-echelon structure more economically attractive for the military, but the current structure is likely to be retained for operational reasons. [Ref. 7:p. 35]

In the reduced funding climate of the 1990's the Navy must also seriously consider performing repairs where they can be completed at the lowest cost while still maintaining readiness.

C. THESIS OBJECTIVE

Commander, Naval Air Systems Command (AIR-43 Aviation Depots) requested that a study be conducted to investigate the feasibility of transferring selected generic depot level engine maintenance and repair capabilities to shore-based

intermediate level facilities. [Ref. 8:p. 1] The F404 engine installed in the F/A-18 aircraft will be used to make recommendations on the feasibility of transferring selected depot repair functions to "selected" AIMDs.

The following specific questions will be addressed:

1. What impact will shifting designated depot maintenance and repair capabilities to the AIMD's have on TAT, WIP times, BCM rates, and work center capacity utilization?
2. What increased manning requirements will be necessary to support the expanded intermediate capabilities and the increased throughput at "selected" AIMD's?
3. What additional support equipment will be needed at the "selected" AIMDs to support expanded maintenance and repair capabilities?
4. What additional facilities will be needed to support the expanded intermediate capabilities?
5. What reduced depot costs will be realized by shifting depot engine maintenance and repair functions to "selected" AIMDs?

D. SCOPE

The scope of this thesis will be limited to evaluating the feasibility of shifting certain F404 depot-level engine overhaul functions currently being performed by NADEP JAX to AIMDs at NAS Cecil Field and NAS Lemoore. The thesis will use Monte Carlo simulation modeling at the AIMD (ashore) level to evaluate the effects of shifting depot level engine overhaul functions to the intermediate level. The cost analysis in this thesis will be limited to a comparison of specific cost

savings that might be achieved by shifting selected engine maintenance and repair functions to these AIMDs. A complete cost analysis is considered beyond the scope of this thesis.

E. PREVIEW

Chapter II will provide background information on current Navy aircraft engine maintenance policy. Chapter III will provide an overview of F404 maintenance capabilities and limitations and detail equipment and processes that would give the "selected" AIMDs increased engine repair capability. Chapter IV will provide an overview of the Monte Carlo simulation, describe development of models, and detail assumptions and data used. Chapter V will contain an analysis of the model's results. Chapter VI will present a summary of the thesis, conclusions reached and recommendations for actions to be taken.

II. BACKGROUND

This chapter will provide background information relating to the Naval Aviation Maintenance Program (NAMP), Aircraft Intermediate Maintenance Department, F404 engine and modules, and funding shortfalls for engine maintenance.

A. THE NAVAL AVIATION MAINTENANCE PROGRAM

The CNO sponsors and directs the NAMP. The CNO issues the program via the six volume OPNAVINST 4790.2E instruction series. The program establishes the CNO's objectives, doctrine, and policies for Naval Aviation Maintenance, and provides details of programs, organizations, and responsibilities. The principal objective of the NAMP is to "achieve and continually upgrade readiness and safety standards established by CNO, with optimum use of manpower, facilities, material, and funds." [Ref. 6:p.1] Achieving this objective encompasses maintaining, manufacturing, and calibrating aeronautical equipment and material at the lowest level of maintenance that attains the optimum use of resources. Equally important are protecting equipment from corrosion, completing systematic preventive maintenance, and gathering and analyzing data to identify areas requiring improvement.

1. Levels of Maintenance

The foundation of the NAMP is the concept of three maintenance levels, which separates aeronautical maintenance into organizational, intermediate, and depot. This concept seeks to improve operational readiness and sustainability by:

1. Classifying maintenance functions by levels.
2. Assigning maintenance functions to a specific level.
3. Assigning maintenance tasks to a level consistent with the depth, scope, and range required to accomplish the task.
4. Accomplishing maintenance tasks or service at a level which ensures economic use of resources.
5. Collecting, analyzing, and using data to assist all management levels. [Ref. 6:p. 3-1]

Task complexity, personnel skill-level requirements, special facility needs, and economic criteria dictate, to a great extent, the specific functions each level of maintenance will accomplish. The three levels can be thought of in terms of a pyramidal hierarchy in that the next higher level builds upon capabilities and functions provided by the lower level. The organizational level is the lowest level and consists of numerous operating sites providing generalized maintenance. The middle level is the intermediate level and consists of mobile or fixed operating sites specializing in removal, repair, and replacement of assemblies, modules or piece parts. The highest level is the depot level which consists of a few operating sites providing specialized maintenance and a

complete overhaul capability. The top two levels exist solely to support their customers at the organizational level.

a. Organizational Level Maintenance

Organizational (O-level) maintenance is performed at the operational site on aeronautical equipment owned by the activity. "The O-level maintenance mission is to maintain assigned aircraft and aeronautical equipment in a full mission capable status while continually improving the local maintenance process." [Ref. 6:p. 3-1] When describing organizational maintenance, Blanchard states:

Organizational-level personnel are usually involved with the operation and use of equipment, and have minimum time available for detailed system maintenance. Maintenance at this level normally is limited to periodic checks of equipment performance, visual inspections, cleaning of equipment, some servicing, external adjustments, and the removal and replacement of some components. Personnel assigned to this level generally do not repair the removed components, but forward them to the intermediate level. From the maintenance standpoint, the least skilled personnel are assigned to this function. [Ref. 9:p. 115]

The NAMP groups O-level maintenance functions under the following categories:

1. Inspections.
2. Servicing.
3. Handling.
4. On-equipment corrective and preventive maintenance. (This includes on-equipment repair, removal, and replacement of defective components.)

5. Incorporation of technical directives (TDs), less support equipment (SE), within prescribed limitations.
6. Record keeping and report preparation.
7. Age exploration (AE) of aircraft and equipment under reliability centered maintenance (RCM). [Ref. 6:p. 3-1]

b. Intermediate Level Maintenance

Intermediate (I-level) maintenance is performed by designated maintenance activities in support of organizations operating aircraft and aeronautical equipment. "The I-level maintenance mission is to enhance and sustain the combat readiness and mission capability of supported activities by providing quality and timely material support at the nearest location with the lowest practical resource expenditure." [Ref. 6:p. 3-1] I-level support facilities may or may not be located near the operational sites. Blanchard provides the following description of I-level maintenance functions:

At this level, end items may be repaired by the removal and replacement of major modules, assemblies, or piece parts. Scheduled maintenance requiring equipment disassembly may also be accomplished. Available maintenance personnel are usually more skilled and better equipped than those at the organizational level and are responsible for performing more detail maintenance. Maintenance tasks that cannot be performed by the lower levels due to limited personnel skills and test equipment are performed here. High personnel skills, additional test and support equipment, more spares, and better facilities often enable equipment repair to the module and piece part level. [Ref. 9:pp. 115-116]

The NAMP groups I-level maintenance functions in the following categories:

1. Performance of maintenance on aeronautical components and related SE.
2. Calibration (Type IV) by field calibration activities which perform I-level calibration of designated equipment.
3. Processing of aircraft components from stricken aircraft.
4. Technical assistance to supported units.
5. Incorporation of TDs.
6. Manufacture of selected aeronautical components, liquids, and gases.
7. Performance of on-aircraft maintenance when required.
8. Age exploration (AE) of aircraft and equipment under RCM. [Ref. 6:pp. 3-1 - 3-2]

c. Depot Level Maintenance

Most depot (D-level) maintenance within the Navy is performed by industrial activities called Naval Aviation Depots or NADEPs. These D-level activities have far more extensive facilities and more highly skilled specialists than either the O-level or I-level activities. The D-level maintenance mission is to "support lower levels of maintenance by providing engineering assistance and performing maintenance that is beyond the capability of the lower level activities." [Ref. 6:p. 3-2] In today's reduced funding climate there is an increasing trend to contract D-level maintenance tasks competitively to the lowest bidder, whether that is a NADEP, a depot in another Armed Service, or private industry. In describing D-level maintenance, Blanchard states:

The depot level constitutes the highest type of maintenance, and supports the accomplishment of tasks above and beyond the capabilities available at the intermediate level. The depot level of maintenance includes the complete overhauling, rebuilding, and calibration of equipment as well as the performance of highly complex maintenance actions. [Ref. 9:p. 116]

The NAMP groups D-level maintenance functions in the following categories:

1. Standard depot level maintenance of aircraft.
2. Rework and repair of engines, components, and SE.
3. Calibration by Navy Calibration Laboratories (Type III) as well as Standards Laboratories (Type I and II).
4. Incorporation of TDs.
5. Modification of aircraft, engines, and SE.
6. Manufacture or modification of parts or kits.
7. Technical and engineering assistance by field teams.
8. AE of aircraft and equipment under RCM.
[Ref. 6:p. 3-2]

B. AIRCRAFT INTERMEDIATE MAINTENANCE DEPARTMENT

AIMD's ashore exist to provide I-level maintenance support to the squadrons based at Naval Air Stations (NAS). This support consists primarily in the form of indirect support by repairing not-ready-for-issue (NRFI) items for the base supply department rotatable pool stocks. AIMD's also provide direct support for squadrons by repairing and returning components sent to the AIMD, conducting non-destructive inspections (NDI)

on squadron aircraft and equipment, providing a ground support equipment (GSE) pool, assisting with incorporation of technical directives and other problem solving activities.

1. Organization

The NAMP standardizes the organizational structure for all AIMD's regardless of their location or the type(s) of aircraft supported. A standardized organization allows effective management within a framework of authority, function, and relationships necessary to achieve improvements in performance, economy of operation, and quality of work. [Ref. 10:p. 3-1] Typical work centers within an AIMD are maintenance material control (Production), airframes, avionics, power plants, quality assurance, and administration. A standardized organization functions well because common basic skills, techniques, and capabilities are needed regardless of the type of aircraft supported. Figure 2.1 below provides the standard ashore AIMD organization chart set forth in the NAMP.

The top three layers in the organizational chart are upper management and staff. The next layer shows the link between AIMD and the base supply department. Supply is not a direct part of AIMD but the relationship is critically important to ensure top notch AIMD support of its customers. The bottom layer of the organizational chart consists of the production divisions. The Power Plants division is of

particular concern to this thesis and will be described in greater detail later. Brief descriptions of some of the key functional components follow.

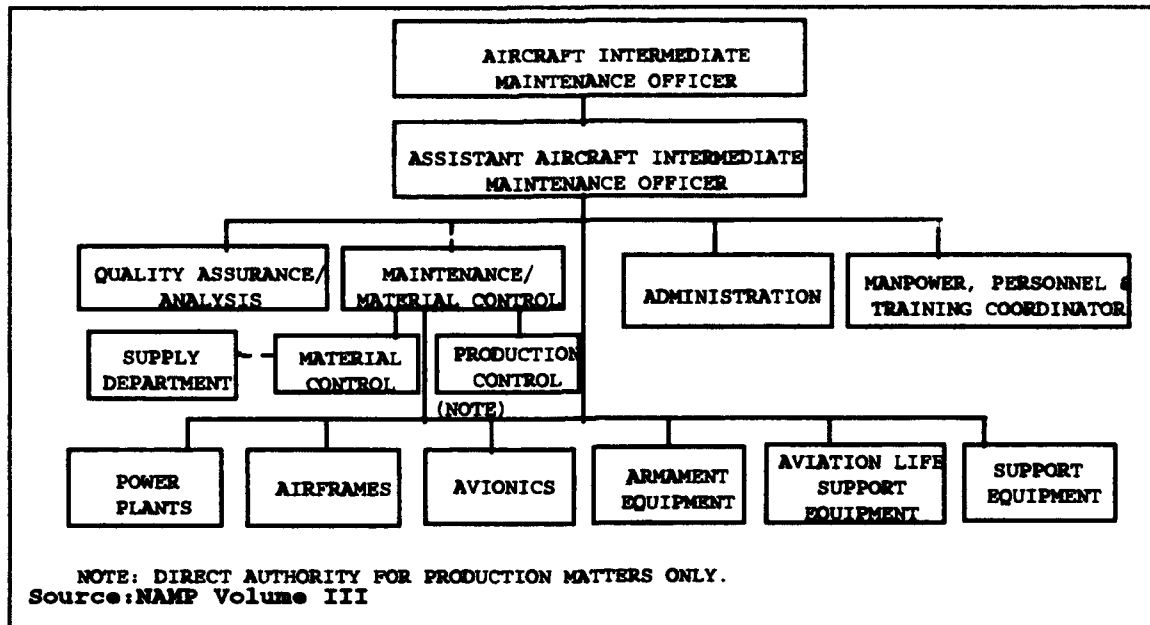


Figure 2.1 - AIMD Organizational Chart (Ashore).

a. Maintenance/Material Control (Production)

Maintenance/Material Control is responsible for production and material support of the AIMD. Included among the many functions are coordinating the activities of the production divisions to ensure efficient movement of components, maintaining liaison with the supply department to ensure material requirements are met, controlling daily workload and assigning priorities, and reviewing maintenance data reports to ensure effective use of manpower and facilities.

b. Quality Assurance/Analysis

The NAMP states "The Quality Assurance concept is fundamentally that of the prevention of the occurrence of defects." [Ref. 10:p. 7-1] Quality Assurance/Analysis (QA/A) is organized with relatively few highly skilled personnel working to achieve the above goal through process monitoring and inspections. The analysis function of (QA/A) develops statistical process control charts by gathering, analyzing, and maintaining information on the quality characteristics of products, the source and nature of defects, and their impact on current operations. [Ref. 10:p. 7-4] QA/A has numerous specific functions including maintenance of the AIMD central technical publications library, monitoring calibration dates for support equipment, training production divisions to improve the quality of their work and inspection techniques and providing feedback information on goals and achievements.

c. Production Control

Production Control works under the direct guidance of the Maintenance Material Control Officer. Their primary purpose is to take "the actions necessary to retain or restore material or equipment to a serviceable condition with a minimum expenditure of resources." [Ref. 10:p. 8-2] To achieve this objective Production Control schedules the workload using procedures set by the Maintenance Material

Control Officer and then coordinates and monitors the production divisions to ensure efficient use of resources.

d. Material Control

Material Control works directly for the Maintenance Material Control Officer. They provide the interface between the AIMD and the base supply department and are responsible for material support to the production divisions. Material Control forwards requisitions for parts and material to the supply department. Upon receipt, parts and materials are expeditiously routed to the requisitioning work centers by Material Control. [Ref. 10:p. 8-93]

e. Power Plants Division

The Power Plants Division of the AIMD is responsible for inspection, repair, and subsequent testing of damaged or non-operable gas turbine engines, accessories, and components. This includes engines used for flight, starting purposes, or auxiliary power. For engines, modules, or components requiring D-level repair or engineering investigation, the Power Plants Division is responsible for preservation and preparation for shipment. The Power Plants Division is also responsible for maintaining accurate engine records and logs and for compliance with applicable power plant bulletins. [Ref. 10:pp. 11-1 - 11-11]

The Power Plants Division of each AIMD is classified as a first, second, or third degree repair activity

for each engine type/model/series (T/M/S) that NAVAIR authorizes the activity to repair. The objective of the three degree gas turbine engine repair program is "to provide the policy and procedures whereby maintenance activities can effectively accomplish their assigned engine maintenance responsibilities." [Ref. 10:p. 11-1] Descriptions of the degrees of repair are as follows:

(1) *Third Degree Repair.* Third degree is the simplest, least involved degree of I-level repair. "This repair encompasses major engine inspections and the same gas turbine engine repair capability as second degree except that certain functions which require high maintenance man-hours and are of a low incidence rate are excluded." [Ref. 10:p. 11-1] To qualify as a third degree repair site for a particular engine, the activity must receive and process between one and 19 engines of that type per year. [Ref. 10:p. 11-2]

(2) *Second Degree Repair.* Second degree repair includes all functions of third degree repair. In addition, this repair capability includes minor module repair through replacement of components or assemblies. The NAMP describes second degree repair as follows:

Repair/replacement of turbine rotors and combustion sections, including afterburners; the replacement of externally damaged, deteriorated, or time-limited components, gear-boxes, or accessories, and minor repairs to the compressor section. Further, the repair or replacement of reduction gearboxes and torque shafts of turboshaft engines and compressor fans of turbofan

engines, which are considered repairable within the limits of the applicable intermediate manual, shall be accomplished by second degree activities. [Ref. 10:p. 11-1]

To qualify as a second degree repair site for a particular engine, the activity must receive and process no less than 20 engines of that type per year. [Ref. 10:p. 11-2]

(3) *First Degree Repair.* First degree repair is the most complex degree of I-level repair. All repairs which are authorized as second or third degree can be completed by a first degree repair activity. In addition, first degree repair involves analytical teardowns to determine the extent of disassembly and repair required to return the engine to service. The NAMP states that this repair includes "compressor rotor replacement/disassembly to the extent that the compressor rotor could be removed." [Ref. 10:p. 11-1] In order to qualify as a first degree repair facility, the activity must receive and process no less than 50 engines of that type per year. [Ref. 10:p. 11-2]

(4) *Repair Beyond First Degree.* The only engines considered beyond I-level capabilities that should routinely be sent to a D-level facility fall into one or more of the following categories:

1. Engines having excessive damage due to fires or having been subjected to fire fighting chemicals internal to the engine.

2. Crash damaged engines (after release by the safety board).
3. Engines subjected to extreme mishandling, such as being dropped.
4. Engines subjected to salt water immersion.
5. Engines exhibiting excessive/extensive corrosion.
6. Engines exhibiting massive oil contamination.
7. Engines that are recommended for removal by an Oil Analysis Laboratory when the specific cause of the impending failure cannot be positively determined and corrected.
8. Engines with total gas path foreign object damage of an extremely destructive nature that will require extensive parts replacement and high man-hour consumption.
9. Engines requiring time compliance power plant changes (PPCs) to parts that cannot be removed by the I-level.
10. Engines requiring life limited part(s) removal that cannot be removed by the I-level. [Ref. 10:p. 11-5]

(5) *Manning and Training.* The primary Navy enlisted rating for maintenance personnel assigned to the Power Plants Division is Aviation Machinist's Mates (AD). In addition, Aviation Electrician's Mates (AE) are assigned to work centers such as the engine test cell. Authorized manning levels for the Power Plants Division as well as the rest of the AIMD are set forth in the OPNAV 1000/2 Manpower Authorization Document. This document is specifically tailored to meet requirements of the organization, details allowed numbers of personnel in each rating, and specifies Navy Enlisted Classification Code (NEC) requirements. The NEC

coding system identifies particular skills and training necessary for designated billets.

Maintenance technicians obtain NEC codes by attending specific maintenance training courses at a Naval Air Maintenance Training Group Detachment (NAMTRADET). NAMTRADET's Cecil Field and Lemoore are F404 training sites. For the F404 Power Plants divisions, the NEC codes required are:

1. 6420: F404 First Degree Technician;
2. 6422: Jet Test Cell Operator;
3. 7166: Jet Test Cell Electrician;
4. 6417: T400 F/A-18 Auxiliary Power Unit (APU) Technician [Ref. 11:pp. 45-47].

C. AIMD NAS CECIL FIELD

NAS Cecil Field is designated a first degree repair site for the F404-GE-400/402 engine used in the F/A-18 aircraft and the TF-34-GE-400B engine used in the S-3B aircraft. [Ref. 1:Encls. (8)and(18)] The main maintenance/repair building houses the administrative offices, work centers, test stands, and storage space for WIP engines, modules and support equipment. The aircraft engine maintenance area totals 64,112 square feet consisting of a main maintenance/repair building of 48,000 sq. ft. and four Turbojet/fan engine test systems (test cells) of 16,112 sq. ft. The test cell types and capabilities are shown in Table 2.1. [Ref. 12]

Organization for and manning of NAS Cecil Field AIMD's Power Plants Division is shown in Figure 2.2. Note that personnel assigned to production control are staff, not production personnel. The Aviation Administration (AZ) personnel assigned to production control are responsible for the maintenance of logs and records and other administrative duties. Figure 2.2 reflects actual assigned manning and does not include all personnel billeted by the manpower authorization document. [Ref. 12]

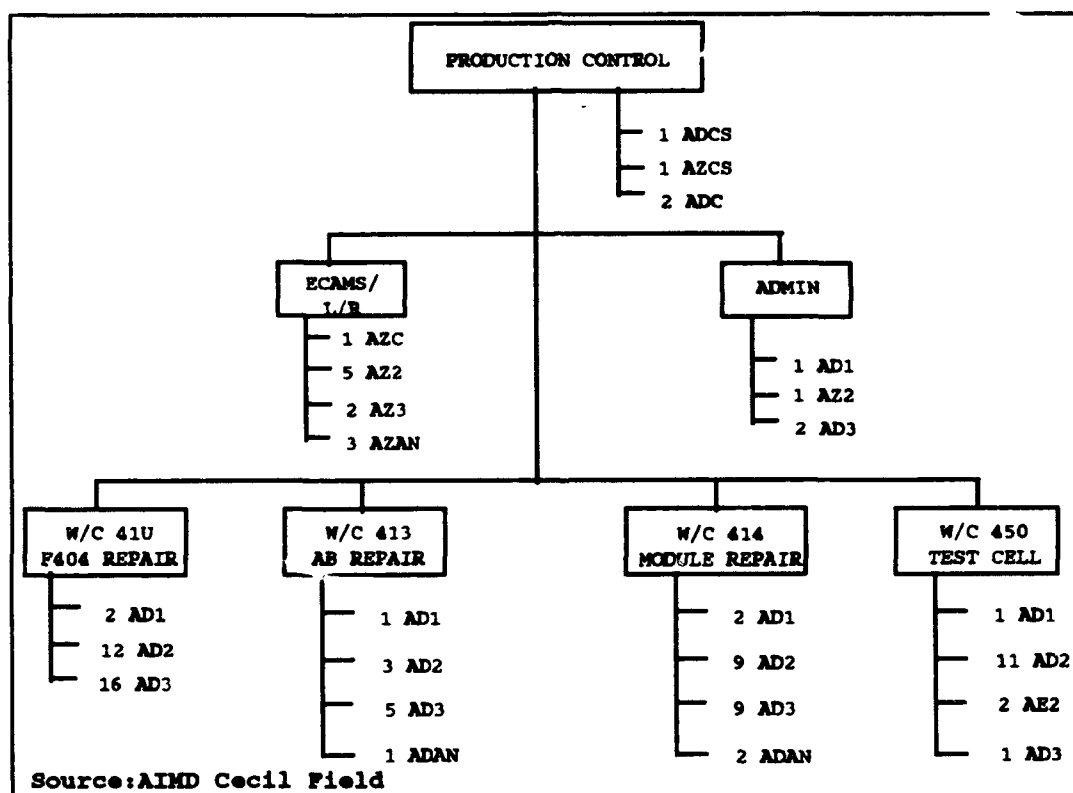


Figure 2.2 - AIMD Cecil Field's Power Plants Division Organization and Manning.

During the period from 1 October 1991 to 30 September 1992, NAS Cecil Field AIMD's Power Plants Division inducted 301 F404 engines and returned 299 of these engines to ready-

for-issue (RFI) condition. This represents an average of about 25 engine inductions per month and an RFI rate of 99.33 percent for the period. [Ref. 12]

TABLE 2.1 - AIMD CECIL FIELD TEST CELLS

Test Cell Type	Engine Capability
A/E 37T-14 (Enclosed)	TF-34
A/F 32T-6A (Enclosed)	F404
A/E 37T-14/15 (Outdoor)	F404
A/F 32T-6A (Enclosed)	TF-34/F404

Source: AIMD Cecil Field

D. AIMD NAS LEMOORE

NAS Lemoore is designated a first degree repair site for the F404-GE-400/402 engine used in the F/A-18 aircraft. [Ref. 1:Encl.(18)] As at Cecil Field, the main maintenance/repair building houses the administrative offices, work centers, test stands, and storage space for WIP engines, modules and support equipment. The aircraft engine maintenance area totals 54,690 square feet consisting of a main maintenance/repair building of 48,000 sq. ft. and three operational Turbojet/fan engine test systems (test cell) of 6,690 sq. ft. One additional test cell type A/F 32T-6 is condemned. The test cell types and capabilities are shown in Table 2.2. [Ref. 13]

Organization of and manning for NAS Lemoore AIMD's Power Plants Division is shown in Figure 2.3. Figure 2.3 reflects only actual assigned manning and does not include all

personnel billeted by the manpower authorization document.
[Ref. 13]

TABLE 2.2 - AIMD LEMOORE TEST CELLS

Test Cell Type	Engine Capability
A/F 32T-10 (Enclosed)	F404
A/F 32T-6 (Enclosed)	F404
A/E 37T-14 (Outdoor)	F404

Source:AIMD Lemoore

During the period from 1 October 1991 to 30 September 1992 NAS Lemoore AIMD's Power Plants Division inducted 295 F404 engines and returned 287 of these engines to ready-for-issue (RFI) condition. This represents an average of about 24.5 engine inductions per month and an RFI rate of 97.28 percent for the period. [Ref. 13]

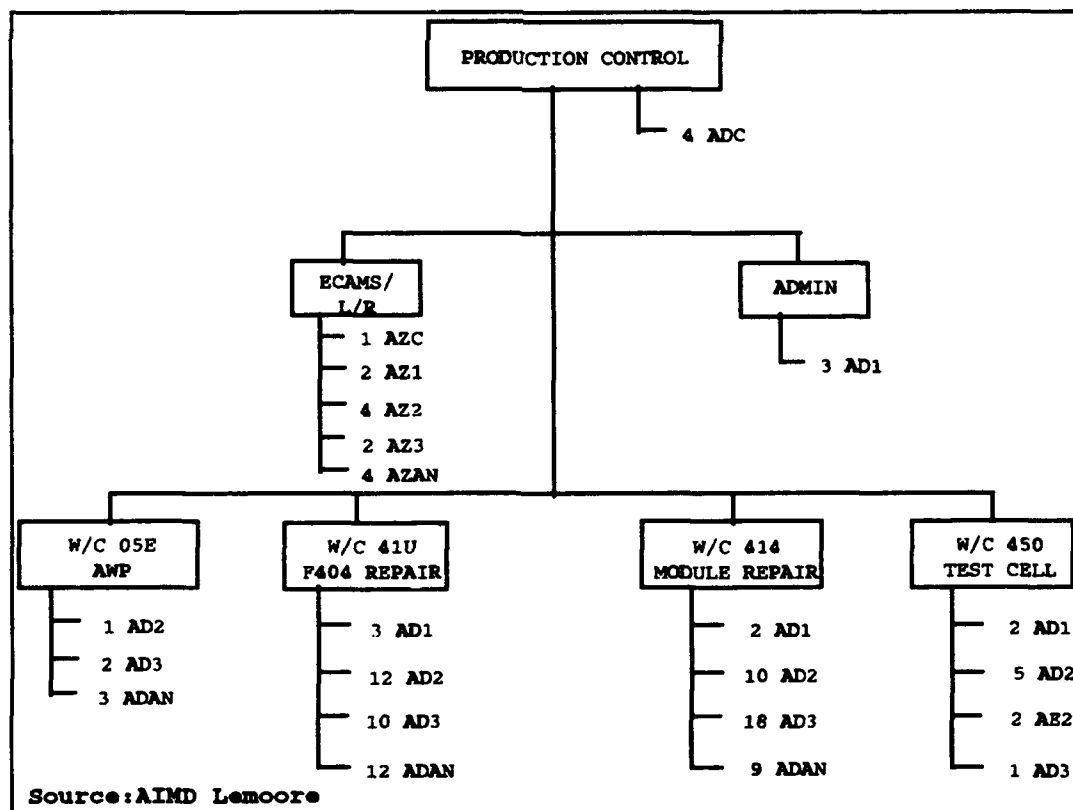


Figure 2.3 - AIMD Lemoore's Power Plants Division Organization and Manning.

E. F404-GE-400/402 ENGINE

1. Background

The F404 program began in 1975 with the award of a development contract to General Electric (GE). The F404 is a derivative of the YJ101, an engine that has the same technology as the B-1A's F101 engine. The basic YJ101 engine was scaled up approximately 10 percent for the F/A-18. [Ref. 14:pp. 2,025 - 2,036] Full scale development of the F404 was completed in 1980. Production began in late 1979 and, by the end of March 1990, 1,900 engines were shipped. The F404 is expected to be in service for 35 years. [Ref. 15:p. 4]

The F404 enhanced performance engine (EPE) is being installed in F/A-18C/D Lot 15 and later aircraft. The EPE(F404-GE-402) was required as a result of new missions (e.g., night attack) and added weight of the newer F/A-18s. Design changes in the EPE included changes to the fan, low-pressure turbine (LPT), afterburner (AB), and exhaust nozzle. [Ref. 15:p. 4]

The development approach used for the F404 engine was a significant departure from previous engine development programs. The F404 program approach emphasized operational suitability, reliability, and maintainability whereas previous engine programs considered performance and weight to be the most important factors. [Ref. 15:p. 4] The F404 was designed to have four times the reliability of the J79 (F-4 engine).

This high level of reliability was to be achieved by using a cost plus type contract with reliability and maintainability award fee incentives. The contract included requirements necessary to achieve engine design simplicity and for conducting rigorous engine testing. [Ref. 15:p. 8]

A second-source contract was negotiated with Pratt & Whitney so that procurement costs could be lowered. General Electric provided drawings and hardware to Pratt & Whitney. The F404 engine was successfully built by Pratt & Whitney but they couldn't compete with General Electric in terms of cost, although studies have been completed which show that this competition forced General Electric to lower its price to the Navy. [Ref. 15:p. 5]

2. Engine Characteristics

The F404-GE-400/402 turbofan engine is a low-bypass turbofan engine with an afterburner. The engine is modular construction, consisting of six major engine modules and an accessories assembly. The engine consists of a three-stage fan, driven by a single-stage low pressure turbine and a seven-stage axial flow compressor, driven by a single stage high pressure turbine. Both the fan and the compressor incorporate a variable geometry system. The engine has a through flow, annular combustor. The engine-mounted accessory gearbox provides the necessary extracted power needed to drive the accessories. The engine is continuously monitored for

critical malfunctions and parts life usage by an Inflight Engine Condition Monitoring System (IECMS). [Ref. 16:p. 1-2]

The propulsion characteristics of the two versions of the F404 engine are shown in Table 2.3. [Ref. 17:p. 5]

TABLE 2.3 - F404-GE-400/402 ENGINE CHARACTERISTICS

PROPULSION CHARACTERISTICS	F/A-18 F404-GE-400 ENGINE	F/A-18 F404-GE-402 ENGINE
Maximum thrust (lb)	16,000	17,700
Weight (dry, lb)	2,161	2,237
Maximum diameter (in)	34.5	34.5
Length (in)	158.0	158.8
Thrust/weight ratio	7:1	8:1

Source: F404 Maintenance Plan

The F404 engine was designed with simplicity in mind. Compared to the J79 engine used in the F-4, the F404 has:

1. 7,700 fewer parts (14,300 versus 22,000).
2. Eight fewer stages (7 compressor, 1 turbine).
3. Three fewer variable stators.
4. A simple gearbox (38 fewer bearings, 28 fewer shafts).
5. A simple fuel system (29 fewer pipes).
6. One combustor liner. [Ref. 15:p.9]

The F404's six major modules will be described in the next subsections. Drawings of the engine and modules appear in Appendix A.

a. Fan Module

The F404 fan module includes a front frame, fan rotor, fan stator assembly, variable geometry system, number one thrust ball bearing, and the number two bearing inner race. The front frame assembly controls the flow of inlet air to the engine. The fan rotor is a three-stage titanium rotor driven by a single-stage low-pressure turbine. Titanium is also used for the fan stator, which consists of stage one (68 vanes), stage two (98 vanes), and stage three (104 vanes). [Ref. 16:p. 1-2]

b. High Pressure Compressor Module

The high pressure compressor (HPC) module consists of a midframe, a seven-stage axial flow compressor rotor, a compressor stator, an outer bypass duct, a rear engine mount ring, a combustion chamber case, the number two roller bearing outer race, the number three ball bearing, fuel nozzles and a fuel manifold, a compressor variable geometry actuation system, and a power takeoff assembly. [Ref. 16:p. 1-6]

c. Combustor Module

The combustor (CMB) module includes a combustion liner, the high pressure turbine nozzle, the nozzle support, and the balance piston static seals. [Ref. 16:p. 1-14]

d. High Pressure Turbine Module

The high pressure turbine (HPT) module consists of two subassemblies; the HPT rotor assembly, and the fan drive

shaft/rear shaft assembly. The single-stage HPT rotor drives the seven-stage compressor rotor. There are 64 HPT rotor blades retained radially in the HPT disk by broached dovetail slots. [Ref. 16:p. 1-15]

e. Low Pressure Turbine Module

The low pressure turbine (LPT) module includes the LPT rotor, HPT shroud and support assembly, LPT nozzle, turbine case, number five roller bearing, turbine exhaust frame, flowpath fairing subassembly, and LPT shroud. The LPT rotor is a single-stage rotor which drives the fan rotor. The turbine rotor consists of a disk with 82 double tanged dovetail blades retained radially by broached dovetail slots. The LPT nozzle is made up of 25 segments with each segment containing 2 vanes. The 25 segments are assembled by the inner spindles to a one-piece LPT air seal. Assembled between each segment is an inner and outer seal strip which prevents air leakage between the segments. [Ref. 16:pp. 1-18 - 1-19]

f. Afterburner Module

The afterburner (AB) module provides the area needed for complete combustion of the exhaust gases and fuel mixture before it passes through the exhaust nozzle. The afterburner module includes an AB case, AB liner, mixer, flameholder, main spraybars, pilot spraybars, distributor valves, thermocouple probes, AB flame sensor, variable exhaust

nozzle (VEN), VEN actuators, VEN position transmitter, exhaust gas pressure probe, and AB igniter. [Ref. 16:p. 1-22]

3. F404 Reliability and Maintenance

a. Reliability

The F404 engine was designed with reliability and maintainability listed among the most important performance criteria during contract negotiations. Despite strict design goals and engine simplicity, the F404 has not met all reliability goals although it has been significantly better than other Navy aircraft engines as shown in Table 2.4 below. Each performance measure represents average data for the three year period from 1987 to 1990. [Ref. 15:p.23]

TABLE 2.4 - FLEET EXPERIENCE WITH F404 AND OTHER ENGINES

Measure of Performance	TF30 F-14	TF41 A-7	J79 F-4	F404 F/A-18	F404 Goals
MTBF' (Hours)	33.7	24.4	29.4	64.7	>72.0
MTBMA (Hours)	14.3	10.1	13.9	19.0	>21.8
Engine Removals/ 1000 EFH	2.6	3.4	2.5	3.7	<2.0
Failed Engine Removals/ 1000 EFH	0.3	0.7	0.5	0.4	<0.5
MMH/EFH (Hours)	1.0	1.5	1.4	0.8	<0.5
MTTR (Hours)	5.1	5.8	8.9	6.2	<7.5

Source:Center for Naval Analysis

b. Maintenance

The maintenance plan for the F404 engine supports the Navy Engine Analytical Maintenance Program (EAMP), which emphasizes reliability centered maintenance (RCM) and, to the maximum extent possible, utilizes an "on condition" maintenance policy. When describing RCM, Blanchard states:

RCM is a systematic analysis approach whereby the system design is evaluated in terms of possible failures, the consequences of these failures, and the recommended maintenance procedures that should be implemented. The objective is to design a preventive maintenance program by evaluating the maintenance for an item according to possible failure consequences. [Ref. 9:p. 237]

In describing "on condition" maintenance, the F404 maintenance plan states:

The on condition maintenance concept applies to all levels of maintenance on the F404 engines, modules, and components. This concept establishes maximum service life for certain parts so that reliable operations can be maintained throughout the life of the engine. To implement this concept, key life limiting parameters are monitored and cumulated by InFlight Engine Condition Monitoring System (IECMS) for use by a Parts Life Tracking System (PLTS). Any engine part that is life limited will have its life specified in parameters calculated by IECMS. The PLTS consists of an on-board computer system and ground station computer that tracks all life limited parts by installation status (aircraft, engine, module, assembly) and updates the amount of life used for each part when usage data is input into the system. Life usage data input to PLTS is calculated and cumulated by the Enhanced Comprehensive Asset Management System (ECAMS) ground station. [Ref. 17:p. 26]

During interviews with the Center for Naval Analysis, fleet personnel indicated the F404 engine was easier

to maintain than other Navy aircraft engines. In particular, they indicated the F404 was easier to install, remove, cannibalize, diagnose, and access. In large part this is due to the modularity of the engine. [Ref. 15:p. 25]

NAS Cecil Field AIMD and MALS-31 provide first degree intermediate level support of the F404 engine for deployed and home-based F/A-18 squadrons on the east coast of the United States. NAVSTA Rota provides limited (primarily module repair) first degree intermediate level support of the F404 engine for deployed F/A-18 squadrons in the Mediterranean. NAS Lemoore AIMD, MALS-11, and MALS-12 provide first degree intermediate level support of the F404 engine for deployed and home-based F/A-18 squadrons on the west coast of the United States. NAS Dallas/MALS-41 provide second degree intermediate level support of the F404 engine for Naval Reserve F/A-18 squadrons. All aircraft carrier (CV) AIMD's and Naval Air Facility (NAF) Atsugi, Japan provide third degree intermediate level support of the F404 engine for their assigned squadrons. [Ref. 1:Encl. (18)]

NADEP JAX is the only depot providing organic F404 engine maintenance and repair capability within the Navy. All maintenance actions listed in the F404 maintenance plan as D-level as well as BCM actions from the first degree intermediate level sites are sent to NADEP JAX for repair. [Ref. 1:Encl. (18)]

F. FUNDING SHORTFALLS

1. Background

As long ago as 1980 NAVAIR personnel recognized that depot funding for both engine overhaul and assembly (component) repair was insufficient to maintain fully mission capable engines in the fleet. NAVAIRINST 4790.17, dated 3 September 1980, states:

One of the major impediments to effective IMA jet engine repair has been the lack of ready-for-issue (RFI) depot repairable assemblies as shelf stock. This has caused engines to be held at the IMA for excessive time awaiting parts, the expenditure of excessive man-hours in cannibalization, and the excessive use of depot customer service facilities. Engines needing only the replacement of a repairable assembly, which is not locally available, are being returned to the depot for repair rather than being repaired at the IMA. The net effect is a circumvention of the established maintenance and supply policies, with attendant loss of supply system demand visibility, and a general inability to effectively accomplish the jet engine intermediate maintenance program defined in the NAMP. Additionally, this lack of locally available repairable assemblies results in fewer RFI engines due to the increased "pipeline" time required for depot processing. [Ref. 18:p. 2]

2. Current Funding Outlook

Depot repair funding shortfalls for components are still evident today as shown in Table 2.5. [Ref. 19] A similar funding shortfall for depot level module repair is shown in Table 2.6. The numbers in parenthesis show the number of units required/funded. [Ref. 20:pp. 63-65]

TABLE 2.5 - FY 93 COMPONENT REPAIR FUNDING SUMMARY (\$ M)

	REQMNT	FUNDED	SHORTFALL
Component Repair	\$920.1	\$708.0	\$212.1

Source: Aviation Supply Office Briefing to NADEP Corporate Board

TABLE 2.6 - FY 93 F404 ENGINE/MODULE FUNDING SUMMARY (\$000)

	REQMNT	FUNDED	SHORTFALL
Eng (36/29)	\$4,873.6	\$3,925.9	\$947.7
AB (7/6)	\$ 93.2	\$ 80.0	\$ 13.2
HPC (58/49)	\$1,532.1	\$1,294.4	\$237.7
FAN (53/40)	\$2,951.0	\$2,227.2	\$723.8
HPT (54/47)	\$3,754.2	\$3,267.5	\$486.7
LPT (38/27)	\$1,459.4	\$1,037.0	\$422.4
CMB (19/9)	\$ 330.5	\$ 156.6	\$173.9

Source: FY-93 Operation & Maintenance Budget Submission

Further complicating this funding shortfall are life limit reductions in the fan disks, the HPT cooling plate, stage three disks and stage one and two spools in the HPC module. The funded and unfunded costs for incorporating these PPC's at the depot level for FY 1993 are shown in Table 2.7. The numbers in parenthesis show the number of units that are funded/unfunded. [Ref. 21]

This section has highlighted the funding problems which the Navy is currently facing. The Navy must evaluate which maintenance level can perform engine repairs at the lower cost. This thesis will attempt to answer that question.

TABLE 2.7 - FY 93 FUNDING SUMMARY(\$000) LIFE LIMIT REDUCTIONS

	FUNDED	SHORTFALL
FAN (105/314)	\$4,070.0	\$22,460.0
HPT (164/136)	\$4,320.0	\$14,540.0
HPC (172/210)	\$1,420.0	\$10,800.0

Source: Naval Air Systems Command

III. AIMD MAINTENANCE CAPABILITIES/LIMITATIONS REVIEW

This chapter will review the F404 maintenance plan and the procedures currently employed by F404 repair work centers at the "selected" AIMDs for the purpose of identifying existing maintenance capabilities and limitations for engine and module repair. The review will then be used to identify additional support equipment, enhanced maintenance capabilities, training and personnel required to increase the repair capability of the AIMDs.

A. F404 MAINTENANCE PLAN REVIEW

The F404 maintenance plan utilized a Level of Repair Analysis (LORA) in compliance with MIL-STD 1390 as "... guidance for repair actions that will be made at depot, intermediate or organizational maintenance facilities based on economics." [Ref. 17:p.10] The plan "...supports the Navy Engine Analytical Maintenance Program (EAMP), which emphasizes reliability centered maintenance and, to the maximum extent possible, utilizes on condition maintenance policy." [Ref. 17:p. 10] The on condition maintenance philosophy establishes a fly to failure or until identified as about to fail by the IECMS because of exceeding established safety of flight parameters. [Ref. 17:p. 14]

In accordance with the F404 maintenance plan, modules and subcomponents are removed for scheduled and corrective maintenance derived from IECMS life usage data as tracked through the PLTS. [Ref. 17:p. 14] The PLTS tracks "...the operating time/cycle counts and Life Use Indices (LUIs) of selected engine components." [Ref. 10:p. 8-4] LUIs are defined as units used to track life usage limits of module subcomponents. PLTS compares this information with the life limits of engines, modules and module subcomponents. The PLTS produces reports "...which specify the time/cycle counts and LUIs remaining on each tracked component before it must be inspected or removed and replaced." [Ref. 10:p. 8-4] At the time of an on condition failure or high-time forced removal determined by PLTS, an engine is removed from an aircraft and turned in to the AIMD for repair.

Upon receipt of the engine from the organizational level activity, AIMD Power Plants Division technicians inspect the engine to determine the discrepant components and review the engine log book for expired life limited components. Upon completion of the engine inspection and log book review, the engine enters the repair cycle. If repair requires the removal of a module, the modules are then sent to the module repair work center.

The F404 maintenance plan identifies a module as a maintenance module and/or a logistics module. [Ref. 17:p. 6] A maintenance module is defined as:

... a combination of components contained in one package, or so arranged as to be mounted together, that can be readily removed or installed onto the engine. They are designed to expedite maintenance and to gain rapid access to internal engine areas. The maintenance module is physically and functionally interchangeable as defined by usable on codes. [Ref. 17:p. 6]

A logistics module is defined as:

... a maintenance module that has been designated a procurable item and is stocked. It is identified by the module name, part number and serial number. Each logistics module will be handled like an engine because it requires specialized shipping containers and Aircraft Equipment Service Records (AESR). [Ref. 17:p. 6]

In the following subsections, each of the six F404 engine modules will be reviewed separately to identify existing repair capabilities and limitations at the AIMD. The abbreviations I-3, I-2, and I-1 used in the following subsections refer to third degree, second degree, and first degree intermediate level repair capability, respectively. Recall from Chapter II that first (I-1) degree intermediate level facilities are the most capable and can perform all maintenance and repair actions that a second (I-2) and third (I-3) degree intermediate level facility can perform. Similarly, second degree intermediate level facilities can also perform all maintenance and repair actions that a third degree intermediate level facility performs.

1. Fan Module

a. Current AIMD Capabilities

The F404 maintenance plan provides for the following maintenance procedures as specified in the Intermediate Maintenance Manuals (IMM) at the intermediate maintenance level:

1. I-3: Remove and replace fan module and remove/install from/into shipping container. Blend fan rotor blades by removing/installing fan upper stator case. Replace stages 2 and 3 blades by removing/installing upper fan stator case.
2. I-2: Remove/replace stage 1 fan blades, no. 1 bearing, no. 2 bearing inner race, seal runner, and rotating air seal. Remove and replace front frame assembly.
3. I-1: Repair fan module by removing and replacing a fan rotor assembly and stator assembly. Repair fan front frame assembly and stator assembly by removing and replacing faulty subassemblies/components specified in Part III-Section B. Repair fan rotor assembly by replacement of blades as specified in IMM. If the number of the damaged blades exceeds the limits specified in the IMM, then the rotor will require balancing and must be sent to the depot. Blend blades within limits. [Ref. 17:p. 15]

In summary, the maintenance plan allows for the removal and replacement of all major subcomponents of the fan module to include repair of the fan rotor assembly by replacement of blades as specified in the IMM.

b. Current AIMD Limitations

The IMM A1-F404A-MMI-210 (Vol II) requires BCMing of the fan rotor to the depot when the disk assemblies reach

high-time limitations and require replacement. Replacement of the disk assemblies requires spin balancing of the reassembled fan rotor. [Ref. 22:WP05800 p. 11] The disk assembly replacement limitation is imposed because the AIMD does not have the capability to spin balance the fan rotor.

2. High Pressure Compressor Module

a. Current AIMD Capabilities

The F404 maintenance plan provides the following maintenance procedures for the HPC:

1. I-3: Remove and re-install outer ducts and replace fuel nozzles (horizontal). Remove and replace the HP compressor module. Install/remove HP compressor module into/from shipping container. Blend HPC rotor blades by removing/installing upper outer duct and upper compressor stator case. Replace blades by removing/installing upper outer duct and compressor stator case.

2. I-2: Remove/replace turbine cooling air tubes, no. 2 bearing support, no. 2 bearing outer race and carbon seal assembly, outer bypass duct, power take-off (PTO) drive assembly and main fuel nozzles (vertical).

3. I-1: Remove and replace components and items specified in Part III-Section B. Repair HP compressor stator assembly by removing and replacing faulty subassemblies/components. Repair HP compressor rotor assembly by limited replacement of blades as specified in the IMM. If the number of blades requiring replacements exceeds the limits specified in the IMM, then the rotor will require balancing and must be sent to depot. Repair other components as specified in Part III-Section B. [Ref. 17:p. 16]

In summary, the maintenance plan allows for the removal and replacement of all major subcomponents of the HPC

module to include repair of the HPC rotor assembly by replacement of blades as specified in the IMM.

b. Current AIMD Limitations

The IMM A1-F404A-MMI-210 (Vol II) requires BCM of the HPC rotor to the depot when the number of compressor blades requiring replacement exceeds 50 for the HPC rotor assembly. [Ref. 22:WP03600 p. 3] The 50-blade limitation is imposed because the AIMD does not have the capability to spin balance the HPC rotor.

3. Combustor Module

a. Current AIMD Capabilities

The F404 maintenance plan provides the following maintenance procedures for the CMB:

1. I-3: Remove and replace combustor module. Install/remove combustor module into/from shipping container. Weld repair combustion liner anti-rotation tabs.
2. I-2: Repair combustor module by removing and replacing combustion liner, HP turbine nozzle segments, and HP turbine nozzle support and seal. Repair liner by welding and re-sizing.
3. I-1: No additional capabilities. [Ref. 17:p. 17]

In summary, the maintenance plan allows for the removal and replacement of all major subcomponents of the CMB module.

b. Current AIMD Limitations

The IMM A1-F404A-MMI-210 (Vol II) requires the CMB module be BCM'd to the depot when the length of a crack exceeds IMM limitations. [Ref. 22:WP0041 p. 2 and WP004200 p. 2] The AIMD is limited in repairing the CMB module by the availability of welding jigs, heat treatment furnaces, cleaning facilities, and the experience level of welding shop technicians.

4. High Pressure Turbine Module

a. Current AIMD Capabilities

The F404 maintenance plan provides the following maintenance procedures for the HPT:

1. I-3: Remove and replace HP turbine module. Install/remove HP turbine module into/from shipping container.
2. I-2: Repair HP turbine module by removing and replacing HP turbine rotor assembly, fan drive shaft, HPT rotor air duct, no. 4 bearing, carbon seal, seal housing, forward seal ring, rotating air seal, oil deflector, and air/oil separator. Repair HP turbine rotor assembly by limited replacement of blades as specified in the IMM. If the number of blades requiring replacement exceeds the limits specified in the IMM, then the rotor will require balancing and must be sent to the depot. Blend HP turbine blades within limits.
3. I-1: No additional capabilities. [Ref. 17:p. 18]

In summary, the maintenance plan allows for the removal and replacement of the majority of subcomponents of the HPT module to include repair of the HPT rotor assembly by replacement of blades as specified in the IMM.

b. Current AIMD Limitations

The IMM A1-F404A-MMI-210 (Vol II) requires BCM of the HPT rotor to the depot when more than a maximum of three pairs of blades require replacement or when disassembly requires removal beyond the front cooling plate or disk from the HPT forward shaft. [Ref. 22:WP04400 p. 12] The six-blade limitation and disassembly beyond the cooling plates are imposed because the AIMD does not have the capability to spin balance the HPT rotor.

5. Low Pressure Turbine Module

a. Current AIMD Capabilities

The F404 maintenance plan provides the following maintenance procedures for the LPT:

1. I-3: Remove and replace LP turbine module. Install/remove LP turbine module into/from shipping container.
2. I-2: Repair LP turbine module by removing and replacing LP turbine rotor assembly, exhaust frame, and "C"-sump assembly, turbine nozzle segments, shrouds, and no. 5 bearing and carbon seal assembly. Stop drill repair HPT shroud support.
3. I-1: Repair LP turbine rotor assembly by limited replacement of blades as specified in the IMM. If the number of blades requiring replacement exceeds the limits specified in the IMM, then the rotor will require balancing and must be sent to the depot. Blend LP turbine rotor blades within limits. Repair no. 5 carbon seals. [Ref. 17:p. 19]

This maintenance plan allows for the removal and replacement of all major subcomponents of the LPT module to

include repair of the LPT rotor assembly by replacement of blades as specified in the IMM.

b. Current AIMD Limitations

The IMM A1-F404A-MMI-210 (Vol II) requires BCM of the LPT rotor to the depot when blade replacement exceeds 20 blades for the LPT rotor assembly. [Ref. 22:WP04800 p. 9] The 20-blade limitation is imposed because the AIMD does not have the capability to spin balance the LPT rotor. The IMM A1-F404A-MMI-210 (Vol II) requires BCM of the LPT exhaust frame to the depot when the length of a crack exceeds IMM weld limitations or is in an area which requires disassembly of the exhaust frame. [Ref. 22] Expanded capability on the LPT exhaust frame would require the positioning of an exhaust frame welding jig and a heat treatment furnace with the capacity to accommodate the frame.

6. Afterburner Module

a. Current AIMD Capabilities

The F404 maintenance plan provides the following maintenance procedures for the AB:

1. I-3: Repair engine by replacement of upper halves of main and pilot spray bar fuel manifolds, distribution valves main and pilot spray bars and VEN actuators. Remove and replace afterburner module. Repair afterburner module by removing and replacing afterburner case, mixer, liner, flameholder, and VEN actuator ring. Repair afterburner case, mixer, liner, flameholder, afterburner main spray bars, actuator ring, VEN flaps and seals and VEN guide link. Install/remove afterburner module into/from shipping container. Install/remove spring hoop damper.

2. I-2: No additional capabilities.
3. I-1: No additional capabilities. [Ref. 17:p. 20]

b. Current AIMD Limitations

The AB liner and case from the AB module are made of titanium. The main limitation faced by the AIMD on the AB module is the lack of welding technicians certified to perform titanium welding and a large titanium welding chamber equipped with a gas analyzer to ensure an inert atmosphere around the entire AB component. These chambers are not currently operational at the AIMDs. Without such a chamber, the AIMDs are primarily limited to a remove and replace function for the AB case and liner. [Refs. 12 & 13]

B. CURRENT MAINTENANCE PROCEDURES

The first step in the repair process of the engine or module at the AIMD is to identify the failed module(s)/component(s). Once a failed module/component is identified, the component is either repaired, replaced with a spare component if available, or cannibalized from other modules which are either awaiting maintenance or parts. If the component is repaired or replaced with a spare component, the engine/module is returned to the RFI spare engine/module pool. If a spare component is not available and no cannibalization opportunities exists, then the module/component is ordered from the supply system. The engine/module is placed in an awaiting parts (AWP) status.

While a failed engine/module is in AWP status, there are several factors which affect total AWP time. These factors include available budget, availability and location of supply system assets, procurement lead times for non-stocked components, and turn around times for depot level repairables (DLRs).

When a module or component requires repair beyond the capability of the AIMD, that module/component is assigned a BCM action taken code and a spare is ordered from the supply system. A BCM is an action taken code defined by the NAMP as:

A term or code used by the intermediate level maintenance activities when repair is not authorized at that level, or when an activity is not capable of accomplishing the repair because of a lack of equipment, facilities, technical skills, technical data, or parts. This code will also be used when shop backlog precludes repair within the time limits specified by existing directives.
[Ref. 10:p. C-4]

AIMD is primarily a repair facility that repairs engines/modules by removal and replacement of modules and components. This approach to engine repair consists mainly of disassembly/assembly with limited repair of components. The depth to which the AIMD can disassemble/assemble the dynamic modules/components of the F404 engine is limited by the inability to spin balance.

Under the current F404 maintenance plan and IMMs, the repair of the dynamic modules (fan, HPC, HPT, LPT) is limited to a specified number of blade replacements. The inability of

the AIMD to spin balance the dynamic components (rotors) results in a BCM action which means the component is forwarded to the depot for repair. Providing the AIMD with spin balancing capability would reduce the BCM rate for these dynamic components.

Similarly, for non-dynamic components such as the LPT exhaust frame, combustor module liner and other subassemblies, and the AB liner, case, and flameholder, the limiting factor to repair is the ability to effect repair using various welding techniques. The factors that limit an AIMD's welding capability are the ability to properly clean and otherwise prepare welded surfaces for welding, non-destructive inspection (NDI) capability, the level of welding certifications and training, and the availability of specific welding procedures for the more exotic metals/components. Thus, increasing the welding capabilities at the AIMDs would reduce the BCM rate for the LPT (i.e., exhaust frame), CMB (i.e., liner), and AB (i.e., case, liner, and flameholder) modules/components.

WIP and TAT for the modules at the AIMD are functions of AWP, cannibalizations and BCM rates. Whenever module components are not available within a reasonable timeframe, the entire module is BCM'd to the depot for repair. This concentrates the depot's repair emphasis on modules as opposed to component rework/overhaul. When major components such as rotors, and combustor/afterburner subassemblies are BCM'd due

to lack of facilities, technical data, or training, the TAT at the AIMD is increased by the AWP time. This AWP time is a function of funding levels and the scheduling priorities established by NAVAIR, the Aviation Supply Office (ASO), and the Type Commanders (TYCOMS) for the NADEPs. The NAMP defines a TYCOM as:

The commands that provide the tactical command with the means to conduct tactical operations. Administration of training, supply, and repair of fleet units are some of their responsibilities. [Ref. 10:p. C-1]

Commander, Naval Air Forces, Atlantic (COMNAVAIRLANT) is the TYCOM for NAS Cecil Field and Commander, Naval Air Forces, Pacific (COMNAVAIRPAC) is the TYCOM for NAS Lemoore.

C. EXPANDED AIMD REPAIR CAPABILITIES

The focus of this study is to identify maintenance functions that might increase capabilities at "selected" AIMDs for the purpose of reducing TAT, AWP, WIP and repair costs. Expanded capability at "selected" AIMDs would reduce the number of BCMs and therefore shorten TAT, and reduce WIP and AWP. Actual WIP times at the AIMD would increase due to the expanded repair functions. However, the overall WIP for repair which currently includes AIMD and depot involvement to repair a component would be reduced. Transportation time, induction inspection times, administrative time, and the higher cost of depot technicians would be saved when a

component is repaired at the AIMD. The following subsections will discuss additional support equipment, personnel and training that might expand AIMD's depth of disassembly/assembly and level of repair capability for the F404 engine, modules and major subcomponents.

1. Spin Balancing Capability

As discussed above, the depth to which the AIMD can disassemble and then reassemble F404 dynamic modules is limited by the number of blades it can replace or the level to which a component can be disassembled without requiring spin balancing in accordance with the IMM. The F404 maintenance plan established spin balancing as a depot level repair capability for the F404 engine.

a. Spin Balancing Machine

The Gilman/Gisholt balance machine, model HB-S-350 (FSCM 07482, manufacturer's P/N 21C8395P01), was procured by the General Electric Company for the Navy to support spin balance requirements for the F404 dynamic components. [Ref. 17:p. 76] This machine meets the F404 maintenance plan requirement for measuring and locating dynamic or static unbalance conditions which will cause vibrations greater than .000010" at the bearing surface during the balancing of F404 rotors. The approximate dimensions of this machine are 12 ft. in length by five ft. in width by six ft. in height and it has a net weight of 1500 lbs. It requires a floor work space of

approximately 100 sq. ft. Electrical requirements are 115 volts AC, 60 HZ, single-phase. It requires no environmental air conditioning or hazardous material abatement for operation. It had a unit cost of \$109,000 in 1978. [Ref. 23:p. 1.01] The Navy currently has four of these machines. Originally, there were two machines at both NADEP JAX and NADEP North Island (NORIS). Because NORIS is no longer a repair site for the F404, those two machines have been transferred to NADEP JAX. Interviews with maintenance technicians at NADEP JAX stated that only two machines are needed for the current and anticipated future workload. [Ref. 24] Therefore, two spin balancing machines could be made available for redistribution to the "selected" AIMDs.

Positioning of these spin balancing machines at "selected" AIMDs would provide the ability to spin balance fan, HPC, HPT, and LPT rotors. The capability to spin balance these components would allow for 100 percent blade replacement on these rotors at the AIMD, thereby reducing the requirement to BCM them to the depot.

Fans and HPCs that have experienced major foreign object damage (FOD) which requires replacement of more blades than allowed in the current IMM at the AIMD or which requires complete blade set replacement due to high time are normally replaced with standard blades. Standard blades require blade tip grinding on a blade tip grinding machine prior to spin balancing. Because of the expense of a stand-alone blade tip

grinding machine and the infrequent demand for this requirement, it is not considered cost effective to position one of these machines at an AIMD.

There are pre-ground blades available from the supply system that can be used to allow 100 percent blade replacement by the AIMD if spin balancing capability were available. Appendix B provides a cost comparison between standard and pre-ground blades for the HPC module. As Appendix B shows, there is not a significant difference between the price of standard and pre-ground blades. It is anticipated that this price difference would be reduced with an increased usage and follow on procurements of pre-ground blades.

Shifting to the increased use of pre-ground blades could have an effect on engine performance due to increased gap between the blade tip and the stator casing, allowing increased bypass. Nonetheless, engine performance parameters are tested in an engine test cell to ensure that the engine meets performance standards. If all performance standards are not met, then the component causing the performance degradation would be BCM'd to the depot for overhaul.

b. Personnel, Training, and Maintenance Requirements

The Gilman/Gisholt spin balancing machine requires only one technician for setup and operation to balance rotors. Discussions with spin balancing machine operators at both NADEPs and the General Electric Company indicated that a

technician knowledgeable in general machining operations with an understanding of jet engine compressor maintenance procedures could be trained to operate the machine in approximately one or two weeks. This training could be provided by the NADEP with on-the-job training. Further, these operators indicated that to obtain and maintain proficiency at balancing the various rotors, technicians must perform balancing procedures routinely. [Refs. 25 & 26]

The maintenance engineers at both NADEP JAX and General Electric Company stated that the Gilman/Gisholt spin balance machine requires very little preventive or corrective maintenance. [Refs. 25 & 27] Since installation of the NADEP JAX spin balancing machine in 1980, it has only required routine maintenance such as pulley belt replacement and calibration of the electronic control unit. No major overhaul or repairs have been required. NADEP JAX is in the process of developing a preventive maintenance program for the spin balancing machine. [Ref. 27]

2. Welding Capability

Welding of F404 engine components is governed by the NAMP, the NAVAIR welding manual NA 01-1A-34, and applicable F404 maintenance manuals. [Ref. 10:p. 11-39] The NAMP states that: "Initial certification is attained by completion of Navy training courses N-701-0007 and/or N-701-0009 or by documented satisfactory completion of equivalent training in

accordance with NA 01-1A-34." [Ref. 10:p. 11-39] The above certification requirements are applicable to both NADEP and AIMD personnel.

Many of the F404 components are BCM'd to the NADEP by AIMD welding technicians because the AIMD does not have the necessary welding jigs, special fixtures, heat treatment facilities, and titanium-certified welders that are currently available at the NADEPs. Many of the jigs and special fixtures were developed by the NADEPs for specific applications. The LPT exhaust frame, combustor module, and AB case and liner all require special fixtures to facilitate welding repair. [Ref. 24] The AB case and liner are made of titanium and repair of these components would require special titanium welder certification not currently available at AIMDs Cecil Field and Lemoore. [Refs. 12 & 13] Training and certification in titanium welding is currently available at NADEP NORIS. Training of welding personnel and procurement and positioning of duplicate jigs and fixtures being used by the NADEPs at the "selected" AIMDs would provide expanded welding capability at the AIMDs.

3. Blade Tip Grinding and Balancing Capability

To further expand an AIMD's capability to increase the depth of disassembly/assembly and repair of the F404 engine and components would require the ability to not only spin

balance but also to measure run-out and provide blade tip grinding capability for the dynamic components.

a. Blade Tip Grinding and Balancing Machine

The F404 maintenance plan established blade tip grinding as a depot level repair capability for the F404 engine. Blade tip grinding and rotor spin balancing is accomplished by using two separate machines at NADEP JAX.

During a visit to the General Electric Company's F404 engine maintenance facility, the researchers were shown the Butler Newall, Inc., blade tip grinding and spin balance machine. This machine will also perform run-out measurements for rotor assemblies. It is apparently the only machine currently available which provides for these three capabilities in one stand-alone unit. [Refs. 28, 29 & 30]

This version of the Butler Newall machine is an enhancement of the blade tip grinding machines currently located at NADEPs NORIS and NORFOLK. The Butler Newall machine uses laser technology to perform required run out and blade tip measurements. All functions of the machine to include spin balancing and blade tip grinding are computer operated. Software is developed in support of specific applications by Butler Newall, Inc. [Ref. 28]

The dimensions of this machine are approximately 28 ft. in length by 20 ft. in width by 10 ft. in height and it has a net weight of 88,000 lbs. It would require a floor work

space of approximately 32 ft. by 40 ft. Electrical requirements for the machine are 350 KVA. It has a self-contained air conditioning unit and is outfitted with environmental abatement equipment. Two machines, including accessories and adapters, with these capabilities have been produced and were installed at commercial airline maintenance facilities in 1992 at a cost of approximately \$2.3 million dollars per machine. These machines are being used by commercial aviation maintenance facilities to support jet engine repair for commercial aircraft. [Ref. 28]

b. Personnel, Training, and Maintenance Requirements

The Butler Newall blade tip grinding and spin balancing machine requires only one technician for setup and operation to grind blades, balance rotors and take run-out measurements. [Refs. 28 & 30]

Discussions with operators at both NADEP NORIS and General Electric Company indicated that a technician knowledgeable in general machining operations with an understanding of jet engine compressor maintenance procedures could be trained to operate the machine in approximately one to two weeks. Butler Newall will provide on-site on-the-job training with machine installation. [Ref. 28] Technicians at the NADEP and General Electric Company indicated that the most important factor in blade tip grinding, rotor balancing, and run out measurement was the experience level of the

technician. Further, they indicated that to obtain and maintain proficiency at blade tip grinding and balancing the various rotors, technicians must perform these procedures routinely. [Refs. 29 & 30]

Since the blade tip grinding machines are not immediately available to the two "selected" AIMDs, they will not be incorporated into the simulation models discussed in the next chapter.

IV. SIMULATION MODEL DEVELOPMENT

This chapter will explain the procedures and techniques used to identify data for determining if there will be significant differences in engine and module turn-around-times (TAT), work in process (WIP) time, BCM rates and capacity utilization of the various work centers at the "selected" AIMDs as a result of transferring selected engine maintenance and repair functions to the AIMD. If there are significant differences, these differences must be evaluated in terms of overall effect on the operation of the AIMD. Queueing theory and a simulation model will be used to analyze the effects on TAT, WIP, BCM rates and capacity utilization at the "selected" AIMDs.

First, a general overview of queueing theory will be discussed. Second, an hypothesis statement will be formulated. Third, a general overview of simulation will be provided. Fourth, data collection will be described. Fifth, the assumptions used in the model will be discussed. Sixth, the parameters used in the model will be provided. Last, an explanation of the simulation model which is used in this thesis research will be discussed.

A. QUEUEING THEORY

Queueing theory studies waiting lines, or in this case, engine and module work-in-process queues at the "selected" AIMDs. Queueing problems start with a sequence of items (such as engines and modules) arriving at a repair facility. Some are immediately inducted for repair while others must wait in the induction queue until a repair channel becomes available. Meanwhile additional engines and modules arrive and must wait. Engines and modules arriving at the "selected" AIMDs either enter an engine assembly/disassembly repair channel or a module repair channel if repair channels are available. If all repair channels are busy, then the engine or module must remain in the queue awaiting repair.

Queueing theory involves two key random variables, interarrival times of items needing repair and repair service times, and their probability distributions. These key random variables form the basis for solving questions concerning the increased capability of the "selected" AIMDs. Their probability distributions will be discussed further in a later section of this chapter.

B. HYPOTHESIS

The parameters of the interarrival and service time distributions will be varied to obtain desired changes in the waiting times and WIP queues. These changes should be influential in the decision making process.

1. Hypothesis Statement

The hypothesis statement has been formulated as follows:

Null Hypothesis (H_0): Changes in the probability distributions of interarrival and service times, as a result of increased engine maintenance and repair capability at the "selected" AIMDs, will have no measurable effect on TAT, WIP, and capacity utilization.

Alternate Hypothesis (H_a): Changes in the probability distributions of interarrival and service times, as a result of increased engine maintenance and repair capability at the "selected" AIMDs, will have a measurable effect on TAT, WIP, and capacity utilization.

2. Approach

The hypothesis will be tested using a simulation model to be described later in this chapter to see if the null hypothesis can be rejected. The approach to test the null hypothesis is as follows:

1. Collect the current engine and module interarrival and service times for the "selected" AIMDs.
2. Calculate TAT, WIP, BCM rates and capacity utilization prior to increasing engine maintenance and repair capability at the "selected" AIMDs.
3. Estimate engine and module interarrival and service times for the increased engine and module maintenance and repair capability for the "selected" AIMDs. These times will be estimated from discussions with NADEP and General Electric maintenance personnel.
4. Calculate TAT, WIP, BCM rates and capacity utilization after increasing engine maintenance and repair capability at the "selected" AIMDs.
5. Compare the changes in TAT, WIP, BCM rates and capacity utilization at the "selected" AIMDs, and determine whether or not the null hypothesis should be rejected or not. In other words, determine whether the change in

interarrival and service times has a measurable effect on TAT, WIP, BCM rates and work center capacity utilization.

C. OVERVIEW OF SIMULATION

Simulation is a process of designing a model of a real world system and experimenting with the model to understand the behavior of the system. An AIMD maintenance facility is an example of a system. Simulation allows a user to examine the effects of making changes to the system without the expense of actually making the changes to the real world system. Simulation can be used to determine whether or not a system will function as intended before the real system is constructed. [Ref. 31:pp. 3-4]

Models can be classified in a number of different ways. A model can be classified as either deterministic or stochastic. A deterministic model ignores randomness of the variables in the model whereas a stochastic model captures the influences of randomness of the variables. Models can also be classified as either static or dynamic. A static model portrays the behavior of the system at a single point in time or the average of the system's behavior over time whereas a dynamic model describes the behavior of a system through time. Spreadsheets are often used for static systems and simulation models are used for dynamic systems.

Finally, models can be classified as either continuous or discrete. A continuous model is one in which the system

variables change continuously over time. A discrete model is one in which the system variables change only at specific points in time. An AIMD is an example of a discrete system because system variables change only when an engine or module arrives for service or departs the system when completed. The models used in this thesis are primarily stochastic, dynamic, and discrete. [Ref. 31:p. 6]

1. Description of SIMAN

To evaluate the effect of increased engine maintenance and repair capability at the "selected" AIMDs, this thesis uses the SIMAN⁶ simulation language. [Ref. 31] SIMAN uses a logical framework which separates the simulation problem into two main components, the model and the experiment.

SIMAN links the model and the experiment together and runs the simulation. At the end of the simulation, SIMAN saves the statistics collected from the experiment as a set of output data. [Ref. 31:p. 95]

A short description of the main features of the model and experiment frames is provided below.

a. Model Frame

The model is a representation of the real world system developed from assumptions about how the real world system operates. It provides a functional description of the

⁶ SIMAN language commands normally appear in capital letters and will be capitalized when used in this thesis.

parts of the system and the nature of the interactions among the parts. The model describes physical elements (engine and module failures, engine and module repairs, engine and module overhaul/repair flow, etc.) and their logical interrelationships. [Ref. 31:p. 62]

The basic structure of a SIMAN program model frame has the following elements:

1. CREATE arrivals.
2. QUEUE to await service.
3. SEIZE the server when available.
4. DELAY by the service time.
5. RELEASE the server.
6. TALLY the time in system and depart.

b. Experiment Frame

The experiment defines variables, attributes, and experimental conditions under which the model is to be exercised. These include run length, initial conditions, resource availability, and types of statistics collected. Because experimental conditions are specified external to the model description, they are easily changed without modifying the basic model definition. [Ref. 31:p.62]

The basic structure of a SIMAN program experimental frame include the following:

1. QUEUES element provides a name for each queue where engines or modules may have to wait for repair.
2. RESOURCES element provides the number of repair channels and number of spares available for use at the AIMD.
3. TALLIES element provides descriptive information about the model's tally records that are used to tally repair times for engines and modules.
4. DSTAT element records time-persistent variables which include the number of engines/modules in the queues, repair channel utilization, and spares utilization.
5. COUNTERS provides a count of the number of engines/modules repaired and the number of engines/modules which are beyond capability of maintenance.
6. SEEDS provides a seed for random number generation.
7. REPLICATE provides information regarding the length of the simulation run and the length of the warm-up period.

2. Description of Probability Distributions

SIMAN has the capability to run stochastic models because it incorporates a mechanism to generate values for the random variables that influence the system. The mechanism is called Monte-Carlo sampling. In Monte-Carlo sampling, a random number generator creates artificial data using a user specified probability distribution. [Ref. 32:p. 559] The use of probability distributions in the generation of the random variables has an effect on the values of those variables. Thus, it is important to choose an appropriate probability distribution as it will affect the simulation results. Law and Kelton state the following regarding probability distributions:

In order to carry out a simulation using random inputs such as interarrival times or demand size, we have to specify their probability distribution. Almost all real systems contain one or more sources of randomness. It is generally necessary to represent each source of system randomness by a probability distribution (rather than just its mean) in the simulation model. [Ref. 33:pp. 325-326]

This thesis uses several types of distributions in the AIMD simulation models. The first distribution used is for the generation of failures of engines and modules installed in aircraft. Engine and module failures over a specific interval of time are discrete events that occur independently. Plotting the frequency of the number of these random engine and module failures that occur over a fixed time interval may result in a distribution pattern closely matching the Poisson distribution. Figure 4.1 provides an example of a typical Poisson distribution. Here x is, say, the number of engine failures over a year. Collecting data over many years allows a percentage to be determined for each value of x which occurred over a year. The probability distribution, $p(x)$, is the decimal fraction reflecting that percentage. The equation for the Poisson distribution is shown in the upper right-hand corner of Figure 4.1.

The mean of the Poisson distribution, λ , is the engines annual failure rate. The reciprocal of λ then represents the mean time between failures (MTBF) in years. Since it is well-known that the time between events in the Poisson process is exponentially distributed, the time between

arrivals (engine failures) can be modeled as being exponentially distributed with a mean of $\mu = 1/\lambda$, or the MTBF. [Ref. 9:p. 30] The AIMD simulation models in this thesis will use the exponential distribution for the arrival of failed

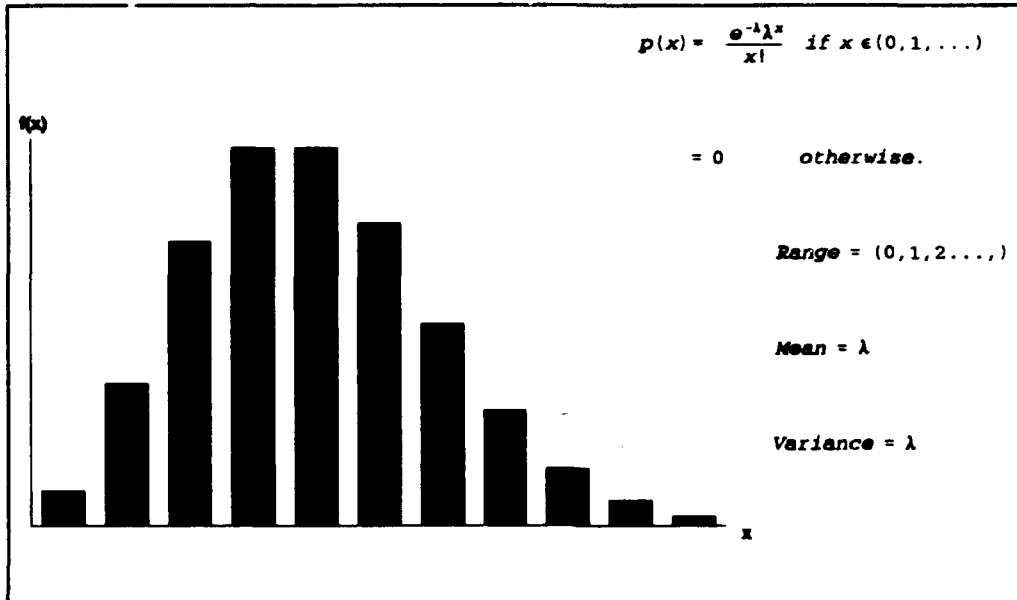


Figure 4.1 - Poisson Distribution.

engines and modules because plotting the frequency of the random engine failures which arrived at AIMDs Cecil Field and Lemoore over a fixed time interval of the previous five years resulted in a distribution matching the Poisson distribution. Figure 4.2 provides an example of an exponential distribution where x is now the time between failures and $f(x)$ is the frequency function.

Although the exponential distribution will be used in the AIMD simulation models as the distribution for the time between arrivals of engines and modules into the system, it may not be a good choice for generating service times for the

engines and modules. Generally, service times do not have the high variability associated with the exponential distribution.

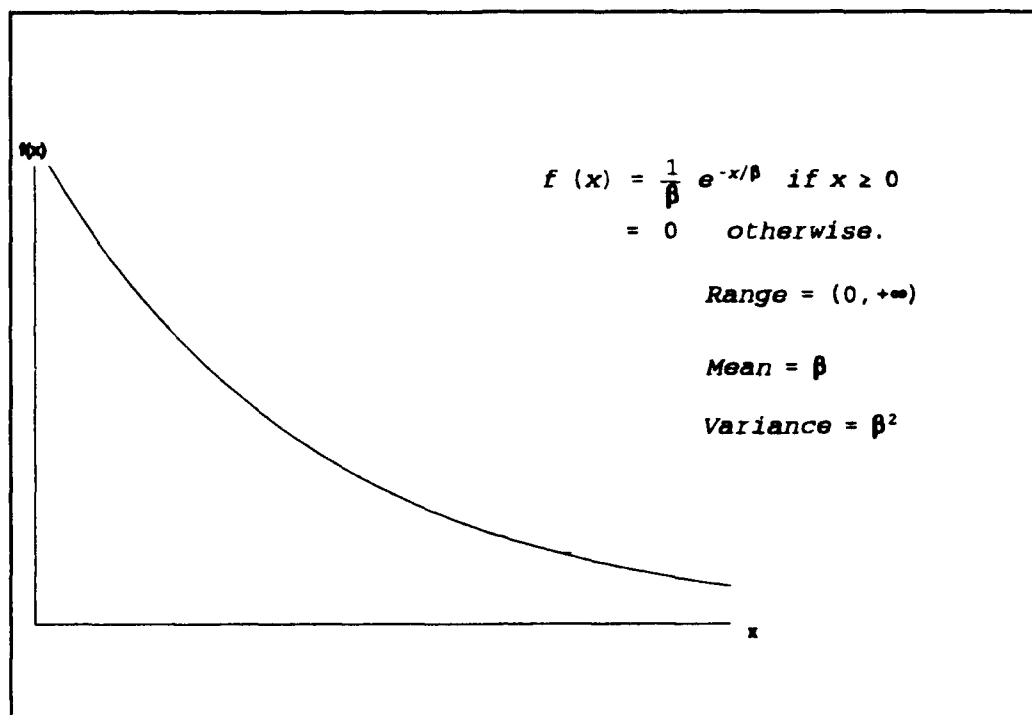


Figure 4.2 - Exponential Distribution.

It might be natural to assume that the normal distribution shown in Figure 4.3 would be a good choice for the distribution of the service times for engines and modules. This is not the case however. The normal distribution generally applies to simple and straightforward maintenance such as repair and replace tasks which require a fixed amount of time with little variation. The normal distribution assumes symmetric variations both above and below the mean, which is seldom true for service tasks. [Ref. 9:p. 40] Further, to use the normal distribution with confidence, a large sample of actual service times is needed to calculate

the mean and the standard deviation. For this thesis, large samples of actual service times were not available. The available data was from AIMD Lemoore and AIMD Cecil Field as well as estimates of the mean service times obtained from NADEP JAX.

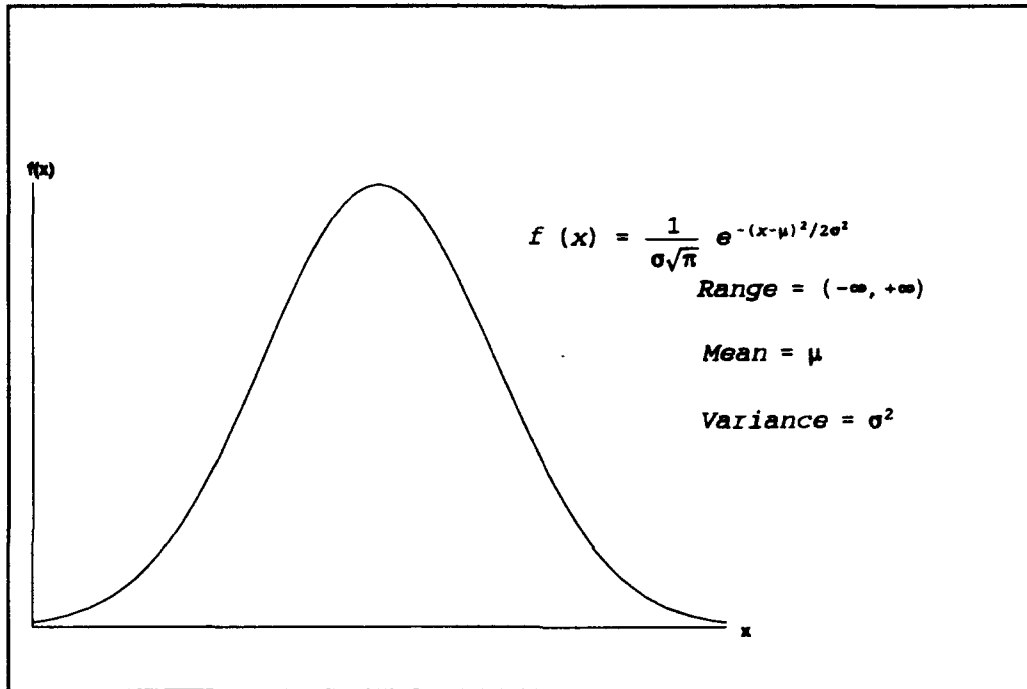


Figure 4.3 - Normal Distribution.

Experience in real-world maintenance tasks provides empirical evidence that any given corrective maintenance task will take a shorter time far more often than it will take a longer time to accomplish the task. However, there may be a small number of maintenance actions where repair times are extensive. This has the effect of skewing the density function to the right.

Two useful distributions which provide variability and can be applied with limited data are the triangular and the

beta distributions. These distributions also have finite tails. That feature is certainly realistic for service times. [Ref. 31:pp. 43-44]

The triangular distribution shown in Figure 4.4 has simplicity as its primary advantage. It is defined by three

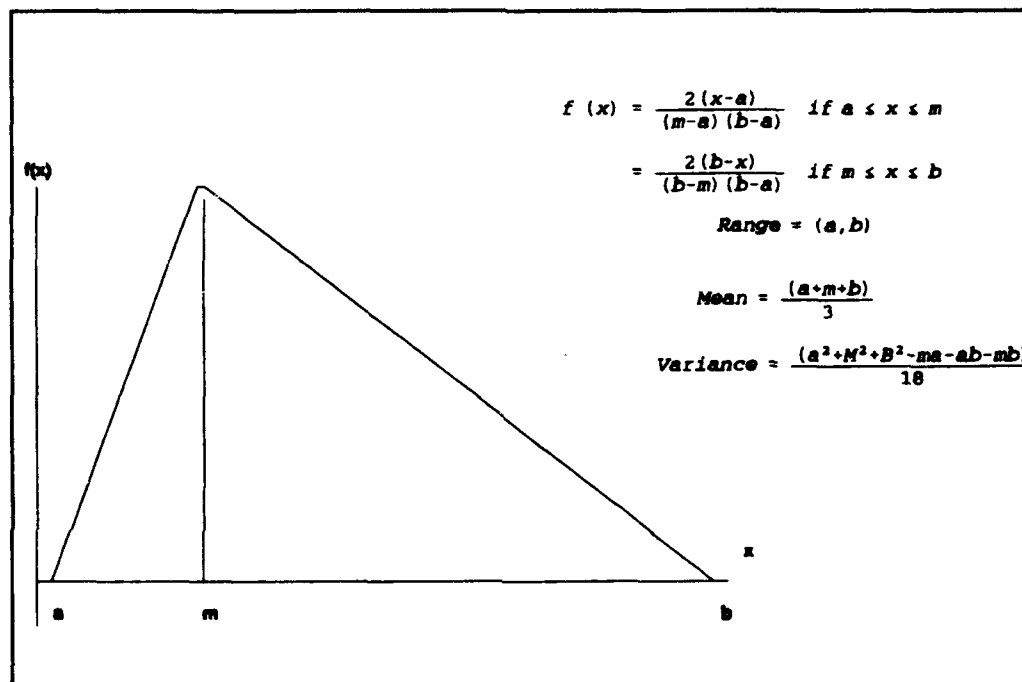


Figure 4.4 - Triangular Distribution.

values: a minimum, a mode, and a maximum. The mode is the data value (service time) that occurs most frequently. All service times fall in the interval defined by the minimum and the maximum values. For the places where the triangular distribution is used in this simulation model, minimum and maximum service time values can be obtained from the available data.

The second distribution suggested when there is limited data is the beta distribution. This distribution is

positive only on the interval 0 to 1. The user must transform the x values of the model to fit within this range. Further, the user must estimate the two distribution parameters, α_1 and α_2 , which specify the shape of this distribution. The requirements to estimate α_1 and α_2 along with the need to transform x values make the beta distribution difficult and less convenient to use than the triangular distribution. [Ref. 31:pp. 43-44] Due to the problems cited above, the beta distribution will not be used in the AIMD simulation models.

An alternative to the beta distribution is to use the log normal distribution. Figure 4.5 provides an example of the log normal distribution. The distribution is skewed to the right and thus also fits empirical experience for service

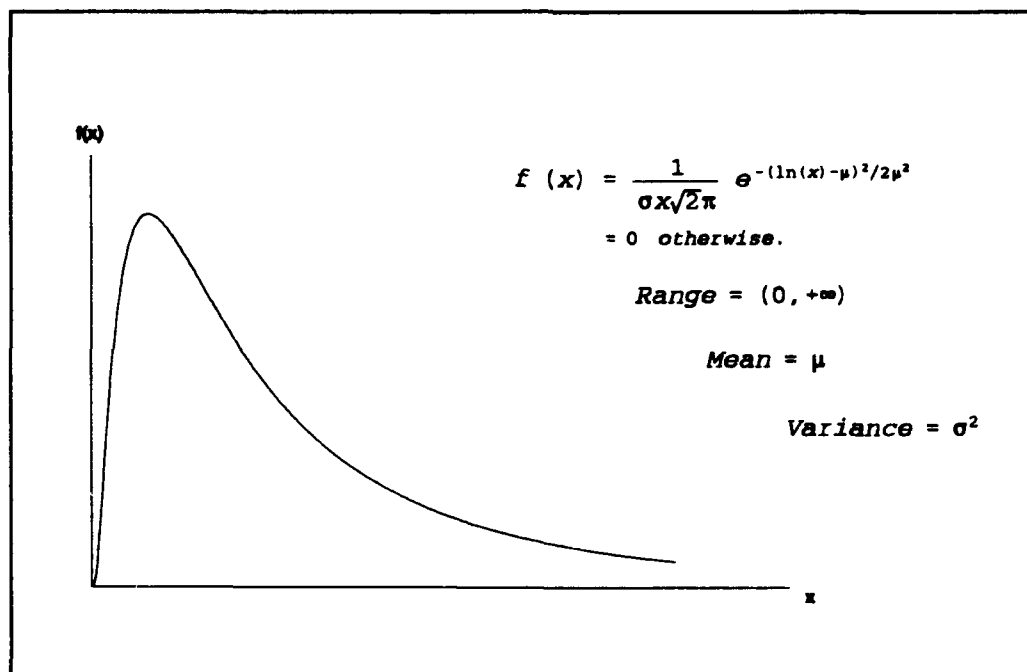


Figure 4.5 - Log Normal Distribution.

times. The log normal distribution applies to most complex maintenance tasks where the task times and frequencies vary. [Ref. 9:p. 40]

Using the log normal distribution also avoids the difficulty of transforming data for using in the beta distribution. The parameters for this distribution can be derived from the mean service times and the standard deviation of those service times. For the AIMD models both of these parameters can be obtained from the available NALDA data.

Using empirical distribution of the repair service was beyond the scope of this study. The distribution which most closely duplicates real world data will be chosen as the simulation model from which outcomes will be analyzed.

D. ASSUMPTIONS USED IN THE SIMAN SIMULATION MODELS

Separate simulation models were developed for AIMDs Cecil Field and Lemoore. Although the simulation models have been developed to reflect the real-world scenario as realistically as possible, there were assumptions made when developing the models. The following list provides the assumptions used in all the simulation runs and the justification for the assumptions.

1. The models assume all East coast aircraft are located at NAS Cecil Field and all West coast aircraft are located at NAS Lemoore. This is necessary to simplify the SIMAN simulation models and does not adversely effect the outcome of the simulations.

2. The SIMAN simulation models assume that the AIMDs operate 24 hours a day when in fact they operate only two eight-hour shifts. Additionally, the SIMAN simulation models assume that the AIMDs operate 7 days a week when in fact they currently operate only 5 days per week. The number of engine, module, and spin balancing repair channels available have thus been reduced to adjust for the 24-hour a day SIMAN model operation. Calculation of available repair channels is discussed in a later section of this chapter.

3. Although COMNAVAIRPAC has not authorized specific spare engine and spare module allowances for NAS Lemoore, the allowances are assumed to be the same as those which COMNAVAIRLANT has authorized for NAS Cecil Field. This assumption is made because the number of aircraft being supported by each of the two NAS's is approximately the same.

4. For the triangular distributions used in the simulation models, the mode values for AWP and average customer wait time (ACWT) were obtained from available AEMS and ASO data but the minimum and maximum values for AWP and average customer wait time (ACWT) are not known. Therefore, these values are assumed. The assumed value of the minimum is 75 percent of the mode, and the assumed value of the maximum is 150 percent of the mode. As discussed earlier this allows for skewing the distribution to the right.

5. The researchers assumed only 83.45 percent of the assigned workers are available for productive work based on the Navy's standard workweek of 40 hours with 33.38 hours available for productive work for shorebased military personnel. [Ref. 34:p. 5-18]

The following list provides additional assumptions used in the expanded AIMD simulation runs and justification for the assumptions.

1. The researchers assumed a 15 percent reduction in component AWP times in the expanded AIMD simulation models. The assumption is based on the increased repair capability at the "selected" AIMDs resulting in fewer BCMS of modules to the NADEPs. Thus, NADEPs receiving fewer modules for repair would be able to increase their repair schedule for

components. This will shorten TAT for components and decrease AWP time for components. Although the volume of parts ordered at the AIMDs will increase, the number of orders will not change significantly and the Supply Department should be able to easily handle the additional workload.

2. The increased spin balancing capability will also necessitate a change in the BCM rates used in the original model, since the AIMD would now BCM fewer modules. Since specific data is not available from which to calculate the reduction in BCM rates, the researchers made the assumption that the BCM rate will be reduced by 65, 70, 50 and 30 percent for the fan, HPC, HPT, and LPT, respectively, based on information provided by NADEP JAX. These percentages reflect the percentage of modules which required only spin balancing and not industrial work at the NADEP [Ref. 24]

3. Increased welding capability at the "selected" AIMDs would not require any specific changes to the internal routing in the original model. However, repair times for the LPT, CMB, and AB modules will increase due to greater repair capability depth and the BCM rates for these modules will decrease. No specific data is available from which to calculate these changes, so the researchers made the assumption that repair times will increase by 25 percent and BCM rates will decrease by 30 percent for the CMB and AB modules. The LPT BCM rate will be reduced by a total of 51 percent based on increased welding and spin balancing (discussed above) capabilities. These assumptions are based on discussions with AIMD technicians and 15 years of personal experience working in aircraft maintenance by one of the researchers. [Refs. 12 & 13]

4. Since standard deviations of the service times for spin balancing are not available, a standard deviation of 20 percent of the mean service time was assumed. As discussed earlier regarding the log normal distribution, this causes skewing of the density function to the right as is supported by empirical maintenance data.

E. INFORMATION COLLECTION

As mentioned earlier, the data collected to use in the model included interarrival times and service times and was gathered from several sources. Interarrival times were

determined from data obtained from the engine production supervisors at the proposed "selected" AIMDs and from the Aircraft Engine Management System (AEMS) data records for the previous five years.

Repair service times were obtained from Naval Aviation Logistics Data Analysis (NALDA) reports separately for the engines and modules. Average customer wait time (ACWT) data for the AIMD as the ordering customer was obtained from FY-92 Naval Sea Logistics Data Center (NAVSEALOGCEN) reports provided by ASO. AWP times for component parts were obtained from AEMS data records and were validated with data provided by ASO. Engine and module RFI spare allowances were obtained from the respective TYCOMS for the "selected" AIMDs.

F. PARAMETERS FOR AIMD SIMULATION MODELS

All simulation models used the exponential distribution for interarrival times of failed engines. Additionally, models which used either the log normal or triangular distribution for repair service times were developed for AIMDs Cecil Field and Lemoore. The following subsections describe important model parameters such as: mean interarrival times, mean service times, number of repair channels, BCM rates, AWP, ACWT, RFI spare allowances for engines and modules, and module failure percentages.

1. Interarrival Times

As stated in an earlier section of this chapter, engine arrivals at the AIMDs are assumed to closely approximate a Poisson distribution. Thus, the interarrival times are expected to follow an exponential distribution. Based on FY-92 data, Table 4.1 below shows the average number of engine arrivals at each AIMD and also the interarrival times used in the model. [Ref. 35]

TABLE 4.1 - AVG. ENGINE ARRIVAL/MO. & INTERARRIVAL TIMES

	AIMD CECIL FIELD	AIMD LEMOORE
AVG. ENG. ARRIVALS PER MO.	25.0	24.5
INTERARRIVAL TIME (HRS)	28.0	29.0

Source: FY-92 AIMS Data Reports

2. Service Times

Separate simulation models which use either the log normal or triangular distribution for repair service times were developed for AIMDs Cecil Field and Lemoore. The distribution parameters derived from the actual service time distributions used in the AIMD models were obtained from FY-92 NALDA data records and are shown in Table 4.2 and Table 4.3. [Ref. 36] The repair times associated with engines and modules are mean values in the log normal model and minimum, mode, and maximum times in the triangular model.

A weighted average was used to calculate average service times for both engines and modules. The frequency of each work unit code failure by engine/module was multiplied by

the average service time for each work unit code. These figures were then summed and divided by the total number of work unit code failures for each engine/module to obtain the weighted average service times. The standard deviations for the service times were obtained using a grouped standard deviation formula. The minimum value was obtained by subtracting one standard deviation from the mean value. The maximum value was obtained by adding two standard deviations to the mean value. As discussed earlier, this allows for

TABLE 4.2 - AIMD CECIL FIELD SERVICE TIMES(HRS)

Work Center	Task	Module	Mean Service Time	Std. Deviation	Minimum Service Time	Mode Service Time	Maximum Service Time
O-Level	Engine Removal	Engine	3.82	.76	2.87	3.82	5.73
O-Level	Engine Install	Engine	5.74	1.15	4.31	5.74	8.61
410	Engine Assy/Disassy	Engine	60.19	9.68	50.56	60.19	79.45
414	Fan Repair	Fan	22.18	15.85	6.33	22.18	53.88
414	HPT Repair	HPT	18.38	5.22	13.16	18.38	28.82
414	LPT Repair	LPT	16.03	8.88	7.15	16.03	33.79
414	HPC Repair	HPC	43.87	70.35	1.00	43.87	184.57
414	CMR Repair	CMR	9.71	1.22	8.49	9.71	12.15
413	AB Repair	AB	9.44	1.85	7.59	9.44	13.14
415	Fan Spin Bal	Fan	2.00	.4	.75	2.00	8.00
415	HPT Spin Bal	HPT	2.00	.4	.75	2.00	8.00
415	LPT Spin Bal	LPT	2.00	.4	.75	2.00	8.00
415	HPC Spin Bal	HPC	4.00	.8	.75	4.00	12.00

Source: FY-92 NALDA Data Reports

skewing the density function to the right as has been evidenced for maintenance service times.

The mean service times for spin balancing are estimates based on personal interviews with maintenance technicians at NADEP JAX and General Electric, Ontario, Ca. [Refs. 24 & 25] Since standard deviations of the service times for spin balancing were not available, a standard deviation of 20 percent of the mean service time is assumed. As stated earlier, this allows for skewing of the density function to the right for the log normal distribution.

TABLE 4.3 - AIMD LEMOORE SERVICE TIMES (HRS)

Work Center	Task	Module	Mean Service Time	Std. Deviation	Minimum Service Time	Mode Service Time	Maximum Service Time
O-Level	Engine Removal	Engine	3.82	.76	2.87	3.82	5.73
O-Level	Engine Install	Engine	5.74	1.15	4.31	5.74	8.61
410	Engine Assy/Disassy	Engine	37.30	18.88	18.42	37.30	75.06
414	Fan Repair	Fan	42.97	27.16	15.81	42.97	97.29
414	HPT Repair	HPT	26.38	20.85	5.53	26.38	68.08
414	LPT Repair	LPT	57.23	67.55	1.00	57.23	192.33
414	HPC Repair	HPC	33.46	24.07	9.39	33.46	81.60
414	CMB Repair	CMB	14.29	2.88	11.41	14.29	20.05
413	AB Repair	AB	18.83	8.50	10.33	18.83	35.83
415	Fan Spin Bal	Fan	2.00	.4	.75	2.00	8.00
415	HPT Spin Bal	HPT	2.00	.4	.75	2.00	8.00
415	LPT Spin Bal	LPT	2.00	.4	.75	2.00	8.00
415	HPC Spin Bal	HPC	4.00	.8	.75	4.00	12.00

Source: FY-92 NALDA Data Reports

3. Engine and Module Repair Channels

To use the AIMD simulation models it is necessary to compute the number of repair channels available for engine assembly/disassembly, module repair, and test cell operation. Discussions with production supervisors at the AIMDs indicated that three-man work teams are assigned in all work centers. [Refs. 13 & 14] The researchers concluded that each three-man team is therefore a repair channel.

The total number of repair channels in the engine disassembly/assembly, test cell and module repair work centers are determined by the number of maintenance man hours available in each work center since, except for the spin balancing repair channel, work center capacity is limited by maintenance man hours available, not by equipment.

The assigned number of personnel in each work center are not available for productive work 100 percent of the time. On any given workday, workers take time off from production for lunch, breaks, meetings, training, sickness, and vacations. The Navy's standard workweek for shorebased military personnel is 40 hours per week with 33.38 hours available for productive work. [Ref. 34:p. 5-18] This equates to 83.45 percent of the assigned workers being available for productive work.

As discussed earlier in this chapter, the SIMAN simulation model operates 24 hours a day, 365 days a year, which equals 8760 available maintenance man hours per year.

AIMDs average 16 hours per day, 255 days a year, which equals 4080 available maintenance man hours per year. Therefore, the number of available AIMD man hours must be adjusted to SIMAN man hours. This is done by multiplying the number of technicians assigned to the work center by the SIMAN adjustment factor of $(4080 \div 8760)$ or 0.4657. The result is the number of available technicians for the AIMD work centers.

To determine the number of channels for each resource (work center), the number of technicians (provided in Figures 2.2 and 2.3 in Chapter II and repeated in Table 4.4) is multiplied by the productivity factor (.8345), then multiplied by the SIMAN adjustment factor (.4657), and then divided by the channel size of three people.

The number of repair channels must be an integer to be used in the SIMAN simulation model. Therefore, after computing the number of available man hours per work center and converting to an equivalent number of repair channels, rounding of the result to the nearest integer was done. Assuming only one spin balancing machine is available for each of the "selected" AIMDs, the number of spin balancing repair channels is limited to one.

Table 4.4 provides the number of available repair channels for the SIMAN models.

TABLE 4.4 - SIMAN MODEL REPAIR CHANNELS

Work Center	AIMD Cecil Field	AIMD Lemoore
41U Engine Assy/ Disassy	$30 \times .8345 \times .4657 \div 3 =$ 3.88 Rounded to 4	$37 \times .8345 \times .4657 \div 3 =$ 4.79 Rounded to 5
413 Afterburner Repair	$10 \times .8345 \times .4657 \div 3 =$ 1.29 Rounded to 1	N/A
414 Module Repair	$22 \times .8345 \times .4657 \div 3 =$ 2.85 Rounded to 3	$39 \times .8345 \times .4657 \div 3 =$ 5.05 Rounded to 5
450 Test Cell	$15 \times .8345 \times .4657 \div 3 =$ 1.94 Rounded to 2	$10 \times .8345 \times .4657 \div 3 =$ 1.29 Rounded to 1
415 Spin Balance	Assumed to be 1	Assumed to be 1

Source: Developed by Researchers

4. BCM Rates for Engine and Modules

At the "selected" AIMDs, there are some maintenance actions which cannot be completed by the AIMD for a variety of reasons including administrative and lack of equipment or expertise. The AIMD simulation models use the BCM rates shown in Table 4.5 to simulate routing some engine and module failures to the depot. These BCM rates were obtained from the FY-92 AEMS data reports. [Ref. 35]

TABLE 4.5 - ENGINE AND MODULE BCM RATES

Component	AIMD Cecil Field	AIMD Lemoore
Engine	.0398	.0271
Fan Module	.1333	.1232
HPT Module	.0955	.3105
LPT Module	.0573	.0625
HPC Module	.0862	.2632
CMB Module	.1163	.0092
AB Module	.0054	.0001

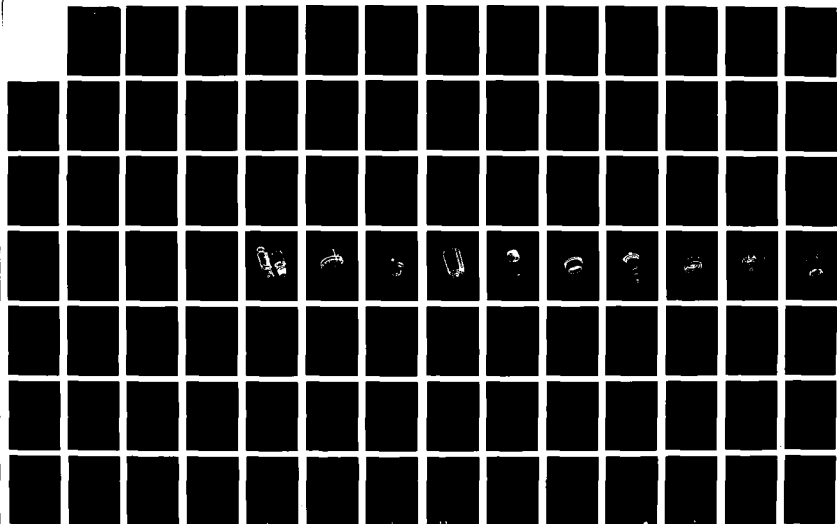
Source: FY-92 AEMS Data Reports

AD-A271 778

A FEASIBILITY STUDY OF EXPANDING THE F-404 AIRCRAFT
ENGINE REPAIR CAPABILITY AT THE AIRCRAFT INTERMEDIATE
MAINTENANCE DEPARTMENT(U) NAVAL POSTGRADUATE SCHOOL
MONTEREY CA S W BARTLETT ET AL. JUN 93

UNCLASSIFIED

NL



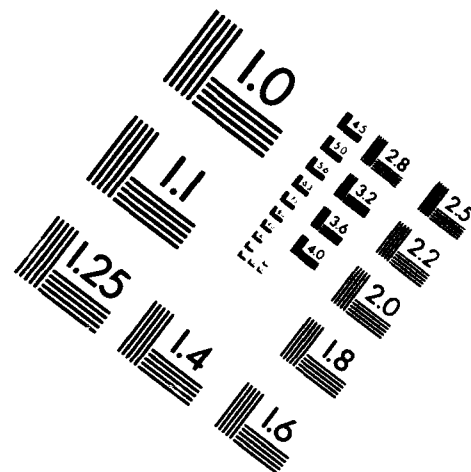
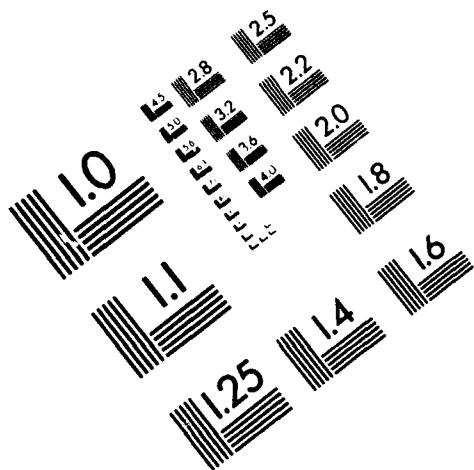


AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

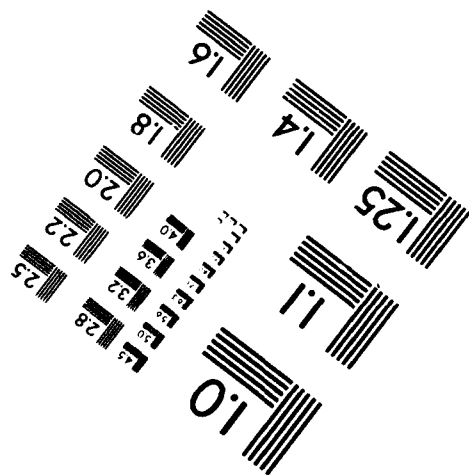
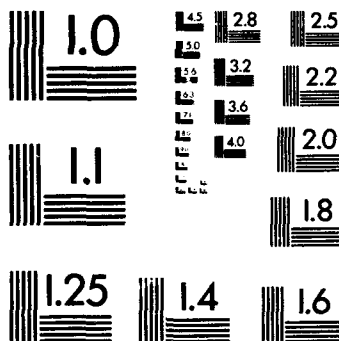
301/587-8202



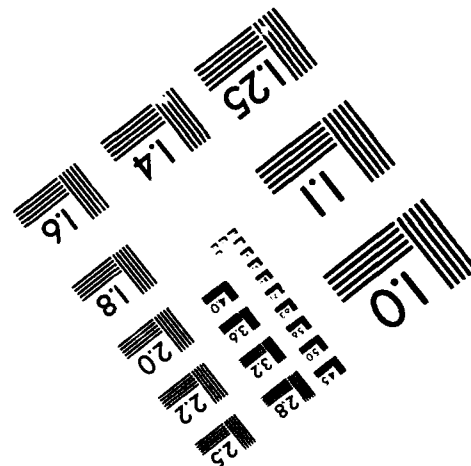
Centimeter



Inches



MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.



5. Awaiting Parts Time and Average Customer Wait Time

Engines and modules being repaired at the AIMDs must often wait for parts after the teardown process. The SIMAN simulation model inserts a DELAY block for the delay time and its distribution is associated with the time that a module must wait for component parts before the buildup process begins. Similarly, when an engine or module has been BCM'd to the depot and a replacement has been ordered, the SIMAN simulation model uses a DELAY block to account for the customer wait time to obtain an RFI engine or module from the supply system. Once a replacement is received, the RFI spare pool at the AIMD is updated.

The average delay times for AWP and ACWT were obtained from FY-92 AEMS data reports and from the NAVSEALOGCEN data reports provided by the Aviation Supply Office [Ref. 35] and are shown in Table 4.6.

TABLE 4.6 - AWAITING PARTS (AWP) AND AVERAGE CUSTOMER WAIT TIME (ACWT) (HRS)

Component	AIMD Cecil Field		AIMD Lemoore	
	AWP	ACWT	AWP	ACWT
Engine	---	221	---	221
Fan Module	792	298	792	298
HPT Module	672	278	168	278
LPT Module	504	317	72	317
HPC Module	744	180	720	180
CMB Module	1656	185	672	185
AB Module	384	238	96	238

Source: FY-92 AEMS Data Reports-AWP/Aviation Supply Office-ACWT

6. Engine and Module Spares

Engine and module spares are necessary to maintain aircraft readiness in the fleet. Acquisition of sufficient spares is necessary to build RFI engine and module spare pools on board ships and at NAS AIMDs to maintain operational availability of assigned aircraft while failed modules are being repaired. AIMDs normally replenish their own engine and module spares through the repair process. However, when an engine or module cannot be repaired by the AIMD, the TYCOM provides authorization to BCM the failed engine or module to the depot for repair. When a BCM action has occurred, a requisition is sent to the supply system for spare replenishment. Table 4.7 shows the AIMD RFI spare allowances authorized by the respective TYCOMS.

TABLE 4.7 - ENGINE AND MODULE RFI SPARE ALLOWANCES

Component	AIMD Cecil Field	AIMD Lemoore
Engine	12	12
Fan Module	12	12
HPT Module	12	12
LPT Module	12	12
HPC Module	12	12
CMB Module	10	10
AB Module	7	7

Source: COMNAVAIRLANT

7. Module Failure Percentages

Upon engine induction to the AIMD, the engine undergoes an inspection in compliance with the maintenance

manual and the engine logbook is reviewed to identify any high time components. The results of the engine inspection and logbook review may result in multiple maintenance actions against more than one module regardless of the reason for engine removal from the aircraft.

When an engine is inducted for repair, the SIMAN simulation model breaks the engine down into the six modules. Failed modules are then directed to the appropriate repair shop for induction. If the repair shop is empty, the failed module enters service. If the repair shop is full, the failed module joins the queue at the shop. Table 4.8 provides the modules failure percentages for each module for the period from 1 October 1991 to 30 September 1992, inclusively. These values were obtained from FY-92 AEMS data reports. [Ref. 35]

TABLE 4.8 - MODULE FAILURES (PERCENT OF ENGINE INDUCTIONS)

Component	AIMD Cecil Field	AIMD Lemoore
Fan Module	44.85%	46.78%
HPT Module	59.14%	64.41%
LPT Module	52.16%	48.81%
HPC Module	38.54%	25.76%
CMB Module	28.57%	36.61%
AB Module	61.79%	69.15%

FY-92 AEMS Data Reports

G. AIMD SIMULATION MODELS

SIMAN models a system by monitoring entities as they pass through the system. The SIMAN model provides a description of the processes entities undergo as they progress through the

system. Entities are any person or object whose movement through the system causes a change in the system. A process is a sequence of operations through which the entities move. [Ref. 31:p. 62] In the AIMD models, entities are either aircraft, engines, or modules. Processes are the repair or service actions and the delays the entities go through during the repair cycle.

The SIMAN model processes based on block diagrams, which are linear, top-down flow diagrams constructed of a sequence of blocks. SIMAN blocks have standardized shapes that serve as an indicator of their function. There are ten basic block types which have numerous specific functions, each of which has its own function name. [Ref. 31:pp. 63-64] They will not be described in this thesis due to complexity of understanding each blocks function without having background training in SIMAN. The block diagram serves as a flowchart for building the model frame of a SIMAN model. Due to the length of the SIMAN block diagrams for the models used in this thesis, only an example of the diagram is shown in Figure 4.6. However, a detailed description of the models are presented below so that a flow diagram is really not needed.

1. Current AIMD F404 Power Plant Model

The first model used in this thesis models the current conditions in the F404 engine repair facilities at NAS Lemoore and NAS Cecil Field. Where there are differences between the

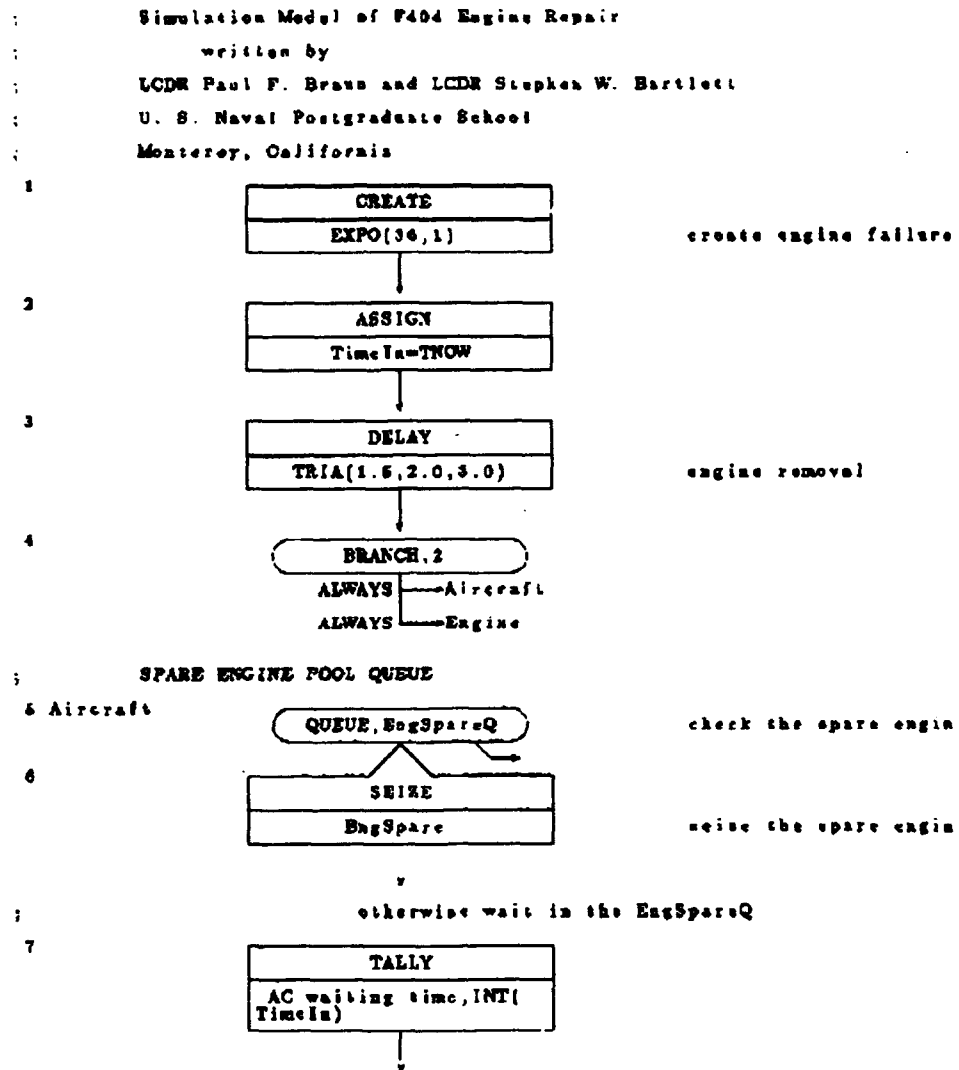


Figure 4.6 - SIMAN Block Diagram.

two facilities, the differences will be discussed. The AIMDs function as first degree repair facilities which includes both engine and module repair. The simulation models for both AIMDs are provided in Appendix C.

The logic of the simulation models is as follows. The CREATE element generates engine failures. ASSIGN sets the clock at the start of the simulation and assigns a time to each entity (aircraft, engine, or module) moving through it. The first DELAY block accounts for engine removal time from an aircraft. The BRANCH block splits the process into two subroutines or segments.

The first segment is the aircraft engine queue. In this segment the aircraft with the engine removed "checks" the engine spare pool at the QUEUE block. If a ready-for-issue (RFI) engine is available, the aircraft "takes it" at the SEIZE block, the aircraft AWP time is tallied at the TALLY block, the engine is installed at the DELAY block, aircraft TAT is tallied, the number of aircraft processed at the COUNT block is increased by one, and the aircraft exits as an entity from the system at the DISPOSE block. If, however, a spare engine is not available, then the aircraft remains grounded and must wait in the queue for the next available RFI engine. Once the entity (aircraft) seizes an engine, it can finish processing through the branch of the system just described.

Meanwhile, in the engine segment, the engine is again sent to either one of two places by the BRANCH block. It is

either BCM'd to the depot for repair or it proceeds to the engine repair queue.

If the engine is BCM'd to the depot, it is first counted at the COUNT block, delayed by the ACWT at the DELAY block until a replenishment requisition is received, released to update the RFI spare engine pool at the RELEASE block, and exits the system as an entity at the DISPOSE block.

However, if an engine is not BCM'd at the BRANCH block, it proceeds to the engine repair queue segment at the QUEUE block. The failed engine must wait in the queue if no engine disassembly repair channel is available. Once a repair channel is available, the engine takes it at the SEIZE block, is delayed for inspection and disassembly at the DELAY block, is released from the engine disassembly repair channel at the RELEASE block, and is then branched to six module spare pool queues and six module repair queues at the BRANCH block.

While in the six module spare pool queues at the QUEUE blocks, the engine seizes a spare for each module if one is available at the SEIZE block or it waits in the queue until a spare module is available. Once the engine seizes all six module spares, they are matched for assembly at the MATCH block.

The engine then returns to an assembly queue where it awaits an engine assembly repair channel at the QUEUE block. If available it seizes the assembly repair channel at the SEIZE block, is delayed by engine assembly time at the DELAY

block, is released from the repair channel at the RELEASE block and is then sent to the test cell queue.

At the test cell QUEUE block, the engine seizes a test cell repair channel if available at the SEIZE block. Otherwise, it waits in the test cell queue until a test cell repair channel is available. It is delayed by the amount of time required in the test cell at the DELAY block, and is released from the test cell repair channel at the RELEASE block. The engine TAT is tallied at the TALLY block, is counted as a repaired engine at the COUNT block, the RFI engine spare pool is increased by one at the RELEASE block, and the engine exits as an entity from the system at the DISPOSE block.

As mentioned above, the engine is separated into the six modules at the first BRANCH block. Then each module proceeds to its repair segment. All module repair segments are simultaneously being completed while the engine is using spare modules for re-assembly. Each module repair segment follows the same basic process. Therefore, only the fan module process will be described.

The first step in the fan repair segment starts with a BRANCH block because only a specified percentage of fans require repair. If no repair is required, the fan is sent to a RELEASE block where it is considered RFI and the RFI fan module pool is increased by one. If repair is required, it is sent to another BRANCH block where the fan is either BCM'd to

the depot for repair or proceeds into fan repair. If the fan is BCM'd to the depot, it is counted at the COUNT block, is delayed for ACWT until a replenishment requisition is received at the DELAY block, increases the RFI fan spare pool by one at the RELEASE block, and its entity exits the system at the DISPOSE block.

When a fan requires repair, it proceeds to a QUEUE block for time awaiting component parts, where it is delayed for AWP time at the DELAY block. Its time after this delay is tallied at the TALLY block and the fan proceeds to the fan repair queue. At the fan repair queue, the fan waits at the QUEUE block until a module repair channel is available. Once a channel is available, the fan seizes it at the SEIZE block, is delayed for a fan repair time at the DELAY block, and is released from the module repair channel at the RELEASE block. The fan WIP time is recorded at the first TALLY block (immediately after leaving the queue) and the fan TAT is recorded at the second TALLY block, the number of fans repaired is increased by one at the COUNT block, and so is the RFI fan spare pool at the RELEASE block. The fan entity exits the system at the DISPOSE block.

The differences in the models between AIMD Lemoore and AIMD Cecil Field are relatively minor. For example, the TYCOM policy for determining allowances for spare modules and engines differs between COMNAVAIRLANT and COMNAVAIRPAC. COMNAVAIRLANT authorizes a specific spare engine and module

allowance for NAS Cecil Field. COMNAVAIRPAC does not authorize a specific spare engine and module allowance for NAS Lemoore. The number of engine and module failures processed per time period also differs between the two AIMDs. Additionally, AIMD Cecil Field uses work center 413 for repairing afterburner modules whereas AIMD Lemoore uses work center 414 for all modules. The number of repair channels also varies between the two AIMDs based on the number of personnel assigned to the AIMD as shown in Table 4.4.

2. Proposed "Selected" AIMD Power Plant Model

The proposed AIMD Power Plants Division model provides the "selected" AIMDs with rotor spin balancing capability for the fan, HPC, HPT, and LPT modules. This is done by adding a new work center (W/C415) which spin balances the modules. The spin balancing capability necessitates changing the original model slightly in the module repair segments for the fan, HPC, HPT, and LPT.

The model also adds an increased welding capability at the AIMDs. This requires a small increase in repair times for the LPT, CMB, and AB modules. The changes to the original model which result are described below.

In the original model the RFI spare module pool was increased by one when a module finished the repair segment. In the proposed AIMD model, a module must first complete the

repair segment and is then directed to a spin balancing segment after which the RFI spare module pool is updated. For the proposed model, once the failed module completes the module repair segment, it is directed to a BRANCH block, where a specified percentage will require spin balancing. If no spin balancing is required, the RFI spare module pool is updated at the RELEASE block and the module entity exits the system at the DISPOSE block. If spin balancing is required, the module is sent to a spin balancing queue at the QUEUE block and seizes a spin balancing repair channel at the SEIZE block. The module is then delayed for the time required in spin balancing at the DELAY block and then released from the spin balancing repair channel at the RELEASE block. The module is then counted as a repaired module at the COUNT block, the RFI spare module pool is updated at the RELEASE block, and the module entity exits the system at the DISPOSE block.

The increased spin balancing capability will also necessitate a change in the BCM rates used in the original model, since the AIMD would now BCM fewer modules. Because specific data is not available from which to calculate the reduction in BCM rates, the researchers used several different reduction values; namely, 65, 70, 50 and 30 percent, respectively, for the fan, HPC, HPT, and LPT, based on information provided by NADEP JAX to see what effect the BCM

rate would have on the various system measures of effectiveness. [Ref. 24]

Increased welding capability at the "selected" AIMDs would not require any specific changes to the routing in the original model. However, repair times for the LPT, CMB, and AB modules will increase and BCM rates for these modules will decrease. No specific data is available from which to calculate the extent of these changes, so the researchers assumed that repair times will increase by 25 percent and BCM rates will decrease by 30 percent. These values were suggested by one of the researchers based on his personal experiences from working in aircraft maintenance for the past 15 years.

V. ANALYSIS OF MODEL RESULTS

This chapter will discuss model validation, present SIMAN simulation model outcomes and then provide an analysis of the model outcomes. Before an analysis can begin, we must first determine whether the model provides a realistic representation of the real world by running the simulation and comparing the output to FY-92 historical data.

A. MODEL VALIDATION

In order to determine whether the SIMAN simulation models described in Chapter IV present a realistic picture of the structure and behavior of the real world capabilities of AIMDs Cecil Field and Lemoore, the models must be validated by comparing simulated outcomes with real world FY-92 NALDA data. As stated earlier, the SIMAN simulation models are driven by available maintenance manhours. All time-related input and output maintainability factors (WIP, AWP, and TAT) are measured in hours per repair action by the SIMAN models. BCM actions, items repaired, and spare utilization are measured in number of units. Ten replications of each simulation were run for 8,760 time units (one year). This is equivalent to simulating a ten-year time period for each run. Additionally, the system was allowed to "warm up" and reach a steady state

operating condition before data collection began. The "warm up" period was 43,800 time units, or five years.

The SIMAN model simulated maintainability factors were tallied during each run and at the end of each simulation replication, their average values were determined. Appendix D provides an example of the SIMAN outcome files for AIMD Cecil Field. The outcome files for AIMD Lemoore are very similar to AIMD Cecil Field but are not included in Appendix D. The spreadsheets in Appendix E were prepared using the outcome files from the ten replications for each SIMAN model. The Appendix E spreadsheets provide the data from which Tables 5.1 through 5.8 were developed in order to compare and validate the SIMAN simulation models with NALDA historical data.

The following subsections will provide comparisons between FY-92 NALDA historical data and output data from the simulation models using either the triangular or log normal distributions for all service times. The distribution type which most accurately duplicated historical data was then used for analysis of data. Determination of the most accurate distribution was done by comparing the average values, standard deviations, and standard errors of the outcomes from SIMAN simulations with FY-92 NALDA data.⁷ The tables in the

⁷ Standard error of the mean is useful for illustrating the consistency of the simulation outcomes. Small standard errors of the mean, as seen in the spreadsheets in Appendix E, are indicative that variation of outcomes from one simulation replication to

following subsections allow comparisons of simulated AWP, WIP, items repaired and BCM rates using the triangular and log normal distributions with the FY-92 NALDA historical data for both AIMD Cecil Field and AIMD Lemoore. The results of these comparisons were used to determine the validity of the SIMAN models and the distribution to be used as a measurement tool for determining the feasibility of expanding AIMD capabilities.

1. AWP Model Validation

Tables 5.1 and 5.2 below provide a comparison of simulated AWP delay times for AIMDs Cecil Field and Lemoore, respectively for the triangular and log normal distributions. As shown in Tables 5.1 and 5.2, the log normal distribution most accurately duplicates the average AWP times from FY-92 NALDA historical data.

another are, in turn, small. Accordingly, the simulations produce very consistent results from one replication to the next. Standard error of the mean is defined by the expression:

$$SE = \frac{s}{\sqrt{n}}$$

$$\text{where: } s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

s is the sample standard deviation, \bar{x} is the sample mean, and n is the number of observations.

TABLE 5.1-COMPARISON OF AWP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD (HRS)

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
Fan AWP	854.32	782.14	792.00	62.32	9.86
HPC AWP	806.02	744.31	744.00	62.02	0.31
HPT AWP	728.06	672.65	672.00	56.06	0.65
LPT AWP	545.80	499.48	504.00	41.80	4.52
CMB AWP	1797.77	1650.79	1656.00	141.77	5.21
AB AWP	417.85	383.21	384.00	33.85	0.79

Source: Developed from SIMAN simulations/NALDA data

TABLE 5.2-COMPARISON OF AWP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE (HRS)

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
Fan AWP	854.55	789.86	792.00	62.55	2.14
HPC AWP	782.69	724.30	720.00	2.69	4.30
HPT AWP	181.78	166.85	168.00	13.78	1.15
LPT AWP	78.42	72.13	72.00	6.42	0.13
CMB AWP	719.54	674.01	672.00	47.54	2.01
AB AWP	103.26	95.58	96.00	7.26	0.42

Source: Developed from SIMAN simulations/NALDA data

2. WIP Model Validation

Tables 5.3 and 5.4 provide a comparison of simulated WIP times for AIMDs Cecil Field and Lemoore, respectively for the triangular and log normal distributions. As shown in Tables 5.3 and 5.4, the log normal distribution most accurately duplicates the average WIP times from FY-92 NALDA historical data.

TABLE 5.3-COMPARISON OF WIP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD (HRS)

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
Fan WIP	26.78	21.62	22.18	4.60	0.56
HPT WIP	76.44	44.04	43.87	32.57	0.17
HPT WIP	20.14	18.29	18.38	1.76	0.09
LPT WIP	19.11	16.06	16.03	3.08	0.03
CMB WIP	10.12	9.73	9.71	0.41	0.02
AB WIP	10.07	9.45	9.44	0.63	0.01

Source: Developed from SIMAN simulations/NALDA data

TABLE 5.4-COMPARISON OF WIP USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE (HRS)

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal Simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
Fan WIP	51.07	42.17	42.97	8.10	0.80
HPT WIP	42.47	34.03	33.46	9.01	0.57
HPT WIP	33.36	25.79	26.38	6.98	0.59
LPT WIP	83.79	55.10	57.23	26.56	2.13
CMB WIP	15.20	14.27	14.29	0.91	0.02
AB WIP	21.61	18.68	18.83	2.78	0.15

Source: Developed from SIMAN simulations/NALDA data

3. Items Repaired

Tables 5.5 and 5.6 provide a comparison of the simulated number of items processed/repared for AIMDs Cecil Field and Lemoore, respectively, for the triangular and log normal distributions. Table 5.5 shows that there is virtually no difference between the results for the two distributions for Cecil Field. Table 5.6 shows that the log normal distribution most accurately duplicates the number of items

processed/repared from FY-92 NALDA historical data for Lemoore.

TABLE 5.5-COMPARISON OF ITEMS PROCESSED/REPAIRED USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal Simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
AC ENG PROCESSED	302.70	302.70	301.00	1.70	1.70
Eng Repaired	289.90	290.00	289.00	0.90	1.00
Fans Repaired	112.80	111.90	117.00	4.20	5.10
HPTs Repaired	155.60	154.80	161.00	5.40	6.20
LPTs Repaired	142.10	144.60	148.00	5.90	3.40
HPCs Repaired	105.10	106.30	106.00	0.90	0.30
CMBS Repaired	75.80	78.50	76.00	0.20	2.50
ABs Repaired	174.90	178.20	185.00	10.10	6.80

Source: Developed from SIMAN simulations/NALDA data

TABLE 5.6-COMPARISON OF ITEMS PROCESSED/REPAIRED USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal Simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
AC ENG PROCESSED	291.60	291.60	295.00	3.40	3.40
Eng Repaired	283.20	284.20	287.00	3.80	2.80
Fans Repaired	114.80	117.40	121.00	6.20	3.60
HPTs Repaired	118.50	126.20	131.00	12.50	4.80
LPTs Repaired	129.70	135.10	135.00	5.30	0.10
HPCs Repaired	56.10	53.30	56.00	0.10	2.70
CMBS Repaired	101.70	100.80	102.00	0.30	1.20
ABs Repaired	193.50	193.00	204.00	10.50	11.00

Source: Developed from SIMAN simulations/NALDA data

4. BCM Actions

Tables 5.7 and 5.8 provide a comparison of the simulated number of BCM actions for AIMDs Cecil Field and

Lemoore, respectively, using the triangular and log normal distributions. Table 5.7 shows little difference in the number of BCM actions using the two distributions for Cecil Field. However, Table 5.8 shows that the triangular distribution most accurately duplicates the number of BCM actions from FY-92 NALDA historical data for Lemoore.

TABLE 5.7-COMPARISON OF BCM ACTIONS USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD CECIL FIELD

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal Simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
BCM Engines	12.50	12.30	12.00	0.50	0.30
BCM Fans	18.40	17.80	18.00	0.40	0.20
BCM HPTs	17.70	16.40	17.00	0.70	0.60
BCM LPTs	7.90	8.60	9.00	1.10	0.40
BCM HPCs	9.80	8.60	10.00	0.20	1.40
BCM CMBs	9.50	8.40	10.00	0.50	1.60
BCM ABs	1.20	1.30	1.00	0.20	0.30

Source: Developed from SIMAN simulations/NALDA data

TABLE 5.8-COMPARISON OF BCM ACTIONS USING ALL TRIANGULAR OR ALL LOG NORMAL DISTRIBUTIONS FOR SERVICE TIMES AT AIMD LEMOORE

Maintenance/ Supply Factors	Triangular Simulation Results	Log Normal Simulation Results	NALDA Historical Data	Difference Triangular/ NALDA	Difference Log Normal/ NALDA
BCM Engines	8.70	7.30	8.00	0.70	0.70
BCM Fans	15.70	16.90	17.00	1.30	0.10
BCM HPTs	60.20	56.70	59.00	1.20	2.30
BCM LPTs	8.60	8.00	9.00	0.40	1.00
BCM HPCs	19.80	14.80	20.00	0.20	5.20
BCM CMBs	0.60	0.80	1.00	0.40	0.20
BCM ABs	0.00	0.00	0.00	0.00	0.00

Source: Developed from SIMAN simulations/NALDA data

In summary, after analysis of the data presented in Tables 5.1 through 5.8, the researchers concluded that the SIMAN

simulation models utilizing the log normal distribution for service times more reasonably approximated the actual maintainability factor values for AWP and WIP produced during FY-92 by AIMDs Cecil Field and Lemoore. For items repaired and BCM actions the results for both types of distributions are close. Therefore, the researchers believe that the SIMAN simulation models using the log normal distribution for service times are preferable for analyzing the feasibility of expanding the capabilities of "selected" AIMDs.

B. ANALYSIS OF CURRENT CAPABILITIES VERSUS EXPANDED CAPABILITIES

This section will compare FY-92 AIMD maintainability factors taken from NALDA data with those maintainability factors produced by the SIMAN simulation models for the expanded AIMD configuration (i.e., "selected" AIMDs). The SIMAN models for the "selected" AIMDs include the incorporation of a spin balance work center and increased welding skills/equipment.

1. Comparison of TAT, WIP, AWP and AWM

Tables 5.9 and 5.10 show the impact on TAT by comparing real-world FY-92 NALDA WIP, AWP and awaiting

maintenance time (AWM)⁸ data with the expanded SIMAN model outcomes for AIMDs Cecil Field and Lemoore, respectively.

In comparing the outcomes from Table 5.9 and 5.10, the simulation models show that engine TAT was decreased by 26 percent and 11 percent for AIMDs Cecil Field and Lemoore, respectively. Similarly, module TATs decreased by an average of 13.2 percent and 12.3 percent, respectively, for the two AIMDs. It is important to note that there is not a direct linear relationship between engine TAT and module TAT. This is because engine TAT is a function of availability of all six modules and not a single module.

One might expect WIP times to rise due to the proposed increased capabilities of the "selected" AIMD. This did not always occur because the increased WIP times for spin balance and welding capability were only small percentages of the original service times. The researchers believe that the small changes in WIP times are due to the high variability of service times as shown in Tables 4.2 and 4.3 and used in the log normal distribution simulation model.

⁸ Awaiting Maintenance time (AWM) is used in the SIMAN simulation models to account for the time an engine or module waits in a queue for an available repair channel. AWM includes all administrative delay time, off-shift time (accounted for in the models by adjusting the number of repair channels) and any delay due to non-availability of resources (manpower and equipment). AWM was calculated for the tables in this chapter by subtracting WIP and AWP from the total TAT.

TABLE 5.9-AIMD CECIL FIELD COMPARISON OF TAT, WIP, AWP AND AWM (HRS)

Engine/Module	TAT	WIP	AWP	AWM
Engine (Current)	253.80	---	---	---
Engine (Expanded)	187.88	---	---	---
Increase/Decrease	-65.92			
Fan (Current)	831.16	22.18	792.00	16.98
Fan (Expanded)	724.85	22.95	672.96	28.94
Increase/Decrease	-106.31	+0.77	-119.04	+11.96
HPC (Current)	821.20	43.87	744.00	33.33
HPC (Expanded)	706.16	42.81	628.39	34.96
Increase/Decrease	-115.04	-1.06	-115.61	+1.63
HPT (Current)	718.76	18.38	672.00	28.38
HPT (Expanded)	616.79	18.33	568.71	29.75
Increase/Decrease	-101.97	-0.05	-103.29	+1.37
LPT (Current)	544.33	16.03	504.00	24.00
LPT (Expanded)	486.79	20.27	434.67	31.81
Increase/Decrease	-57.54	+4.24	-69.33	+7.81
CMB (Current)	1695.47	9.71	1656.00	29.76
CMB (Expanded)	1462.68	12.16	1409.08	41.44
Increase/Decrease	-232.79	+2.45	-246.92	+11.68
AB (Current)	419.74	9.44	384.00	26.30
AB (Expanded)	368.29	11.77	328.99	27.53
Increase/Decrease	-51.45	+2.33	-55.01	+1.23

Source: Developed from SIMAN model results/NALDA data

TABLE 5.10-AIMD LEMOORE COMPARISON OF TAT, WIP, AWP AND AWM (HRS)

Engine/Module	TAT	WIP	AWP	AWM
Engine (Current)	82.70	---	---	---
Engine (Expanded)	73.47	---	---	---
Increase/Decrease	-9.23			
Fan (Current)	849.18	42.97	792.00	14.11
Fan (Expanded)	734.65	43.13	672.52	19.00
Increase/Decrease	-114.53	+0.16	-119.48	+4.79
HFC (Current)	777.30	33.46	720.00	23.84
HFC (Expanded)	672.30	32.75	615.36	24.19
Increase/Decrease	-105.00	-0.71	-104.64	+0.35
HPT (Current)	210.99	26.38	168.00	16.57
HPT (Expanded)	190.23	26.64	143.08	20.51
Increase/Decrease	-20.76	+0.26	-24.92	+3.94
LPT (Current)	145.40	57.23	72.00	16.17
LPT (Expanded)	149.68	67.52	61.01	21.15
Increase/Decrease	+4.28	+10.29	-10.99	+4.98
CMB (Current)	708.17	14.29	672.00	21.88
CMB (Expanded)	610.18	17.83	566.68	25.67
Increase/Decrease	-97.99	+3.54	-105.32	+3.79
AB (Current)	136.34	18.83	96.00	21.51
AB (Expanded)	142.12	23.22	81.64	37.26
Increase/Decrease	+5.78	+4.39	-14.36	+15.75

Source: Developed from SIMAN model results/NALDA data

The AWP times in the expanded models for both AIMD Cecil Field and Lemoore decreased by approximately 15 percent. This is the result of decreasing AWP times by 15 percent in the expanded simulation model because of the assumption that increased repair capabilities of "selected" AIMDs would result in fewer BCMs and shorter ACWT times for components repaired at the NADEP. This further validates the outcomes provided by the simulation models.

Module AWM times increased by an average of 22 and 29 percent, respectively, for AIMDs Cecil Field and Lemoore. Since the number of repair channels for both the current and expanded models were held constant, modules in the expanded model must wait longer for a repair channel because AWP times were decreased and WIP times were slightly increased.

2. Comparison of Items Processed/Repaired and the Effects on BCM Rates

Tables 5.11 through 5.13 show the impact on BCM rates by adding a spin balancing work center and increased welding capability to AIMDs Cecil Field and Lemoore. In Tables 5.11 and 5.12, a comparison of FY-92 NALDA data with expanded SIMAN model outcomes is presented to demonstrate the improvements in BCM rates. Table 5.13 focusses on only the BCM rates. As can be seen, the BCM rates for the modules were reduced by an average of 46 percent and 48 percent, respectively, for AIMDs Cecil Field and Lemoore.

TABLE 5.11-COMPARISON OF NUMBER OF ITEMS REPAIRED AND BCM ACTIONS FOR AIMD CECIL FIELD

FY-92 NALDA DATA					EXPANDED MODEL DATA			
Module	Items Inducted	Items Repaired	BCM Actions	BCM Rate(%)	Items Inducted	Items Repaired	BCM Actions	BCM Rate(%)
Fans	139.00	121.00	18.00	12.95	136.00	126.10	6.90	7.27
HPTs	148.00	131.0	17.00	11.48	158.00	150.80	7.20	4.55
LPTs	144.00	135.00	9.00	6.25	138.10	133.30	4.80	3.47
HPGs	66.00	56.00	10.00	15.15	71.60	69.70	1.90	2.65
CMBs	112.00	102.00	10.00	8.92	111.40	105.30	6.10	5.47
ABs	205.00	204.00	1.00	0.48	193.00	192.60	0.40	0.21

Source: Developed from SIMAN model results/NALDA data

TABLE 5.12-COMPARISON OF NUMBER OF ITEMS REPAIRED AND BCM ACTIONS FOR AIMD LEMOORE

FY-92 NALDA DATA					EXPANDED MODEL DATA			
Module	Items Inducted	Items Repaired	BCM Actions	BCM Rate(%)	Items Inducted	Items Repaired	BCM Actions	BCM Rate(%)
Fans	138.00	121.00	17.00	12.32	133.00	126.10	6.90	5.19
HPTs	190.00	131.00	59.00	31.05	180.90	150.80	30.10	16.64
LPTs	144.00	135.00	9.00	6.25	137.50	133.30	4.20	3.05
HPGs	76.00	56.00	20.00	26.32	75.50	69.70	5.80	7.68
CMBs	103.00	102.00	1.00	0.97	106.00	105.30	0.70	0.66
ABs	204.00	204.00	0.00	0.00	192.00	192.00	0.00	0.00

Source: Developed from SIMAN model results/NALDA data

TABLE 5.13-COMPARISON OF FY-92 NALDA BCM RATES WITH EXPANDED MODEL BCM RATES FOR AIMDs CECIL FIELD AND LEMOORE

AIMD CECIL FIELD					AIMD LEMOORE			
Module	NALDA BCM Rates	Expanded BCM Rates	BCM Rate Diff +/-	% Diff in BCM Rates	NALDA BCM Rates	Expanded BCM Rates	BCM Rate Diff +/-	% Diff in BCM Rates
Fams	12.95	7.27	-5.68	-56.14	12.32	5.10	-7.22	-42.13
HFTs	11.48	4.55	-6.93	-34.13	31.05	16.04	-14.41	-46.43
LFTs	6.25	3.47	-2.78	-55.52	6.25	3.05	-3.20	-48.50
HPNs	15.15	2.65	-12.50	-17.49	26.32	7.00	-18.64	-28.18
CMBS	8.92	5.47	-3.45	-41.32	0.97	0.00	-0.97	-98.04
ABs	0.48	0.21	-0.27	-43.75	0.00	0.00	0.00	0.00

Source: Developed from SIMAN model results/NALDA data

Table 5.14 shows the projected number of modules that would be spin balanced at the FY-92 induction rate. This represents the simulated number of modules which the simulation models project could be repaired at the "selected" AIMDs rather than being BCM'd to the NADEP.

TABLE 5.14-PROJECTED NUMBER OF MODULES SPIN BALANCED AT THE AIMDs

MODULE	AIMD CECIL FIELD	AIMD LEMOORE
Fams	9.90	9.40
HFTs	6.90	23.40
LFTs	3.00	2.50
HPNs	8.30	11.90
Total	28.10	47.20

Source: Developed from SIMAN model results

3. Comparison of Work Center Utilization between Current and Expanded Simulation Models

Work center utilization rates were calculated by dividing total work center WIP time by the total operating

time for a given period of time. Table 5.15 shows the effect on work center utilization by comparing the current SIMAN model outcomes (because the NALDA data base doesn't provide such information) with the expanded SIMAN model outcomes for AIMDs Cecil Field and Lemoore.

TABLE 5.15-COMPARISON OF WORK CENTER UTILIZATION RATES FROM SIMULATION MODELS (AVERAGE PERCENT)

WORK CENTER	AIMD CECIL FIELD			AIMD LEMOORE		
	Current Siman Model	Expanded Siman Model	Percent Change	Current Siman Model	Expanded Siman Model	Percent Change
W/C 410 (Engine)	9.73	49.77	+0.08	23.84	24.06	+0.92
W/C 450 (Test Cell)	4.98	4.97	-0.20	7.69	7.70	+0.13
W/C 414 (Module Rpr)	49.44	55.52	+12.30	51.31	61.86	+20.56
W/C 413 (AB Rpr)	19.24	24.23	+25.94	N/A	N/A	----
W/C 415 (Spin Bal)	N/A	0.81	----	N/A	1.37	----

Source: Developed from SIMAN model results

The important point in analyzing work center utilization rates is to determine if sufficient capacity exists to support expanding the capabilities of the AIMD and the increased engine/module throughput. Monitoring of work center utilization rates is one means of identifying production bottlenecks. Although a work center utilization rate of 100 percent may sound efficient, it is not. In fact, this rate can only be achieved if there is always another NRFI engine/module awaiting induction. Depending on the situation, work center utilization rates around 80 percent can cause production bottlenecks and leave little room for surge capacity.

As shown in Table 5.15, AIMDs Cecil Field and Lemoore utilization rates derived from the current configuration simulation model range from 4.98 to 49.73 percent and 7.60 to 51.31 percent, respectively. The percent change for AIMDs Cecil Field and Lemoore utilization rates in the expanded simulation model range from -0.20 to +25.94 percent and +0.13 to +20.56 percent, respectively. The highest average work center utilization for AIMD Cecil Field's expanded model was found in work center 414 (module repair) at 55.52 percent. For AIMD Lemoore's expanded model, the highest average work center utilization was also found in work center 414 at 61.86 percent. The proposed spin balance work center utilizations are 0.81 and 1.37 percent for AIMDs Cecil Field and Lemoore, respectively. These rates may seem quite low but they need to be viewed in relation to the test cell operation which are 4.97 and 7.70 percent for AIMDs Cecil Field and Lemoore, respectively. That is, they should be judged on the added capability they provide and the number of BCM actions which are avoided. Cost saving attributed to the reduced number of BCM actions will be discussed in the next section. No bottlenecks appear to have developed in the expanded models because work center utilization rates are still much less than 100 percent.

4. Comparison of Spare Utilization

Table 5.16 shows the effect on spare engine and module utilization (average number of spares used) by comparing current SIMAN model outcomes with expanded SIMAN model outcomes for AIMDs Cecil Field and Lemoore. Table 5.16 shows that the current authorized number of engine/module spares (refer to Table 4.7) is sufficient to support the "selected" AIMDs configuration at FY-92 throughput rates. Table 5.16 also shows lower spare utilization for the expanded model than is required in the current model configuration. This can be attributed to the shorter engine and module TAT's in the expanded models. As shown in Table 5.16, the simulation model also indicates that average engine spares could be reduced by two engines at the two AIMDs.

TABLE 5.16-COMPARISON OF AVERAGE SPARE ENGINE/MODULE UTILIZATION (UNITS)

COMPONENT	AIMD CECIL FIELD			AIMD LEMOORE			Total Spares Reduced at Both AIMDs
	Current SIMAN Model	Expanded SIMAN Model	Diff Spare Usage	Current SIMAN Model	Expanded SIMAN Model	Diff Spare Usage	
Engine	8.09	6.29	-1.80	2.75	2.47	-0.28	2.08
Fan	9.94	9.38	-0.56	10.61	9.76	-0.85	1.13
HPC	9.34	8.50	-0.84	4.95	5.34	+0.39	0.45
HPT	10.87	10.48	-0.39	4.83	4.09	-0.74	1.13
LPT	8.54	7.69	-0.85	2.17	2.13	-0.04	0.89
CMB	9.89	9.59	-0.30	7.67	6.98	-0.69	0.99
AB	6.35	6.30	-0.05	2.63	2.67	+0.04	0.01

Source: Developed from SIMAN model results

C. PROJECTED COST SAVINGS RESULTING FROM EXPANDED CAPABILITIES

A primary driver for expanding the capabilities of "selected" AIMDs is the potential for cost savings. It is useful to identify what those savings might be and how they could be achieved. While it is beyond the scope of this thesis to do a complete life cycle cost analysis, a cost benefit analysis of just implementing spin balancing and increased welding capability will be provided. Cost savings resulting from the "selected" AIMDs will be analyzed in terms of reduced BCM actions, increased throughput and manpower requirements. Appendix F provides an illustrated cost benefit analysis for expanding the capabilities of AIMDs Cecil Field and Lemoore as discussed in Chapter III. This was projected over a ten-year period using SIMAN simulation data.

To determine the AIMD costs, the researchers included the following requirements for expanding the AIMDs' capabilities:

1. Spin Balancing Machines (one each site).
2. Welding fixtures/equipment (initial and recurring costs for both sites).
3. Maintenance costs for spin balance machine (recurring).
4. Utility costs for operation of spin balance machine (recurring).
5. Set-up costs (initial for both sites).
6. Personnel (initial and recurring for both sites, 2 spin balance technicians and 2 welders).
7. Training (initial and recurring for both sites).

Spin balancing machine costs were determined from the Support Equipment Recommendation Data (SERD) for the F404 engine. [Ref. 23:p. 1.01] These costs were stated in FY-79 dollars. The FY-79 dollars were converted to FY-92 dollars using economic indexes. [Ref. 37:Table B-3] Welding fixtures/equipment, set-up and training costs were estimated by the researchers. Maintenance and utility costs for the spin balancing machine were also estimated. Based on conversations with NADEP JAX, the researchers determined Wage Grade 9, step 1 as the paygrade required for additional spin balance and welding technicians at the "selected" AIMDs. [Ref. 24] Labor costs of \$12.11 per hour (1992 Federal Wage Rate Schedules for Jacksonville, Florida) times 2080 hours per year provided total labor costs per year for each technician.

Outyear AIMD cost projections were held constant in real dollars. [Ref. 38:p. 4] To determine the total present value of the costs, the totals were discounted using DoD's standard 10 percent discount factor. [Ref. 38:p. 2] The present value of the costs assuming purchase of new equipment and hiring of civilian personnel to augment spin balance and welding work centers was \$1,193,307.06. If existing spin balance machines were made available, installation accomplished with organic manpower and training of Navy personnel as spin balance technicians, the present value of the costs would be decreased to \$162,078.04.

To determine the benefits, the researchers used the projected reduction in BCM'd modules (rounded) from Tables 5.11 and 5.12 and multiplied by the NADEP JAX labor/overhead cost per module. [Ref. 39:Encl] These labor/overhead costs were combined in the cost benefit analysis presented in Appendix F to avoid publishing commercially sensitive data. The costs were stated in FY-92 real dollars. Outyear NADEP labor/overhead cost projections were held constant in real dollars. [Ref. 38:p. 4] To determine the final net present value of the benefits, the totals were discounted using DoD's standard 10 percent discount factor. [Ref. 38:p. 2] The present value of the benefits was \$6,124,770.54.

The total net present value (NPV) is the difference between the present value of the benefits and the present value of the costs. The total net present value (NPV) in FY-92 dollars over the ten-year period assuming purchase of new equipment and hiring of civilian technicians to augment spin balance and welding work centers is \$4,931,463.48. If existing spin balance machines were made available, installation accomplished with organic manpower and training of Navy personnel as spin balance technicians, the NPV would be increased to \$5,962,692.50 in FY-92 dollars.

D. ANALYSIS OF INCREASED THROUGHPUT AND EFFECTS ON TAT AND WORK CENTER UTILIZATION

This section will analyze the effect on TAT and work center utilization rates when the throughput is increased from 300 to 400 engines per year at each AIMD under the expanded capabilities. The analysis uses the expanded simulation model with all parameters the same as above except for the throughput rate. As mentioned earlier, simulations can provide indications of potential bottlenecks and the need for additional manpower requirements, if any.

Tables 5.17 and 5.18 shows the work center utilization and TAT outcomes of the simulation models when 400 engines per year are processed at each AIMD. Table 5.17 shows that work center utilization rates increase as one would expect. The important point that Table 5.17 shows is that existing channels have the capacity to handle the increased workload.

TABLE 5.17-COMPARISON OF WORK CENTER UTILIZATION WHEN PROCESSING 400 ENGINES PER YEAR AT "SELECTED" AIMDs

ITEM	AIMD CECIL FIELD			AIMD LEMOORE		
	Expanded 300 Engines Per Year	Expanded 400 Engines Per Year	Increase/ Decrease	Expanded 300 Engines Per Year	Expanded 400 Engines Per Year	Increase/ Decrease
WC 4111	49.77	65.43	+15.66	24.06	32.58	+8.52
WC 450	4.97	6.60	+1.63	7.70	10.37	+2.67
WC 414	55.52	73.19	+17.67	61.86	88.52	+26.66
WC 413	24.23	31.73	+7.50	N/A	N/A	N/A
WC 415	0.81	1.01	+0.20	1.37	1.86	+0.49

Source: Developed from SIMAN model results

However, as Table 5.18 clearly indicates, engine TAT increases significantly at both AIMDs when the number of engines being processed increases from 300 to 400 engines per year. Table 5.18 shows that WIP and AWP had very small changes. This indicates that AWM queues are increasing due to the greater TAT resulting from the additional throughput.

Finally, AIMDs Cecil Field and Lemoore expanded models processing 400 engines per year were run with various combinations of increased numbers of repair channels to determine the effect on TAT. This was done by adding one repair channel at a time to a work center to determine the effect on both work center utilization and TAT.

The simulation model identified work center 414 as the bottleneck. As stated earlier, work center utilization rates above 80 percent can lead to production bottlenecks. Table 5.17 shows work center 414's utilization rate at 88.52 percent for Lemoore. Adding one repair channel to work center 414 provided 25- and 123-hour reductions in engine TAT for AIMDs Cecil Field and Lemoore, respectively.

When the number of repair channels for work center 414 was increased by 33 percent to equal the throughput increase, the simulation model showed a decrease in the engine TAT, but did not achieve the previous engine TAT when processing 300 engines per year. As would be expected, the model did show that spares utilization was increased when the processing rate increased to 400 engines per year (refer to last four pages of

Appendix E). Additional simulations showed that engine TAT could then be reduced by either increasing the number of spares or by decreasing AWP time.

TABLE 5.18-COMPARISON OF TAT, AWP, AND WIP WHEN PROCESSING 400 ENGINES PER YEAR AT "SELECTED" AIMDS (HRS)

ITEM	AIMD CECIL FIELD			AIMD LEMOORE		
	Expanded 300 Engines Per Year	Expanded 400 Engines Per Year	Increase/ Decrease	Expanded 300 Engines Per Year	Expanded 400 Engines Per Year	Increase/ Decrease
Eng TAT	187.88	283.85	+95.97	73.47	241.01	+167.54
Fan TAT	724.85	729.71	+4.86	734.65	740.91	+6.26
HPC TAT	706.16	767.14	+60.98	672.30	706.36	+34.06
HPT TAT	616.79	626.29	+9.50	190.23	197.81	+7.58
LPT TAT	486.79	492.06	+5.27	149.68	172.25	+22.57
CMB TAT	1462.68	1582.28	+119.60	610.18	678.06	+67.88
AB TAT	368.29	371.70	+3.41	142.12	405.46	+263.34
Fan AWP	672.96	674.51	+1.55	672.52	674.63	+2.11
HPC AWP	628.39	635.58	+7.19	615.36	609.64	-5.72
HPT AWP	568.71	571.59	+2.88	143.08	143.72	+0.64
LPT AWP	434.67	427.98	-6.69	61.01	60.43	-0.58
CMB AWP	1409.08	1406.32	-2.76	566.68	569.82	+3.14
AB AWP	328.99	329.48	+0.49	81.64	82.16	+0.52
Fan WIP	22.95	22.56	-0.39	43.13	43.48	+0.35
HPC WIP	42.81	46.39	+3.58	32.75	33.16	+0.41
HPT WIP	18.33	18.51	+0.18	26.64	26.41	-0.23
LPT WIP	20.27	20.06	-0.21	67.52	75.73	+8.21
CMB WIP	12.16	12.07	-0.09	17.83	17.84	+0.01
AB WIP	11.77	11.77	0.00	23.22	23.57	+0.35

Source: Developed from SIMAN model results

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

Today's challenge is to maximize the life, utilization and capabilities of Naval aircraft at the most affordable cost. To that end this study focused on the feasibility of transferring selected "high payback" F404 engine depot level functions from NADEP JAX to AIMDs Cecil Field and Lemoore. The researchers identified spin balance capability and enhanced welding skills as the "high payback" functions to evaluate. The researchers, using simulation software, determined that transferring these capabilities is feasible, more affordable and maximizes the use of available resources.

The study centered on maintenance and repair of the F404 modular engine at the AIMDs. Simulation employing the SIMAN language was used to model the F404 engine repair process at the AIMD and to investigate the impact of expanding capabilities of the intermediate maintenance level. This expansion would consist of adding a spin balance machine in the module repair work center and providing additional welding jigs, fixtures, and training for the welding shops at the "selected" AIMDs. Before and after expansion simulation models were run to study the effects on engine and module TAT, WIP, BCM rates, and work center utilization rates.

Using the expanded AIMD simulation model results, a cost/benefit analysis was completed to identify if expansion of the "selected" AIMDs would be cost-effective. Additional simulations of the expanded model were also run to determine the effect that increasing the throughput rate would have on TAT and work center utilization rates. The next section will provide conclusions and the last section will provide recommendations.

B. CONCLUSIONS

The following conclusions provide answers to the research questions stated in Chapter I. In particular, the conclusions address the impact on TAT, WIP, BCM rates and work center utilization when designated depot maintenance and repair capabilities are shifted to "selected" AIMDs. These impacts were estimated using the simulation models. The "selected" AIMDs were AIMDs Cecil Field and Lemoore. The simulation models provide strong indications that expansion of the "selected" AIMDs is feasible. Specifically, the SIMAN simulation models furnish evidence that:

1. For model validation, the SIMAN simulation models using the log normal distribution for repair times most accurately duplicated the real-world FY-92 data for AIMDs Cecil Field and Lemoore.
2. Engine and module TAT would be significantly reduced if the capabilities of the "selected" AIMDs are increased by adding a spin balance work center and expanded welding equipment/skills.

3. WIP times increase by only a small percentage in the expanded models. This small percentage increase is attributed to the relatively small amount of time required to spin balance the dynamic components and provide expanded welding repair. This additional WIP time results from processing those modules which would have previously been BCM'd to the depot. Note that, as stated in item 2 above, the TAT for all engines/modules processed was reduced despite the small increases in WIP time.

4. BCM rates for modules are greatly reduced by the expanding the "selected" AIMDs capabilities.

5. The AIMDs work center utilization rates remain below maximum capacity and no bottlenecks developed as a result of the expanded capabilities. The "selected" AIMDs have the manpower capacity necessary to process an average 300 engines per year with no additional manpower in existing work centers.

6. Work center utilization rates are greater when processing 400 engines per year. When the number of engines processed was increased to 400 engines per year, a bottleneck developed in work center 414 which resulted in an increase in TAT. Increasing the number of channels (i.e., manpower) decreased the TAT but not to the level achieved when processing only 300 engines per year. The model showed that AWP time must be reduced or number of spares increased to achieve TATs comparable to those for the 300 engine per year level.

7. When processing 300 engines per year the number of spare engines/modules required at the "selected" AIMDs to maintain fleet support could be reduced if the AIMDs' capabilities were expanded.

From the above conclusions, the researchers further conclude that the addition of spin balance and enhanced welding capability will reduce TAT with minimal increases in WIP time. The resulting decreased BCM rates contribute substantially towards that TAT reduction.

This study determined that the most effective means of increasing F404 support at the "selected" AIMDs could be

accomplished by the installation of a spin balance machine at these sites because it would eliminate many dynamic components from being sent on to the NADEP. Chapter III provides the floor space and electrical requirements necessary for installation of a spin balance machine. From site visits and interviews with AIMDs Cecil Field, Lemoore and NADEP JAX personnel, the researchers conclude that floor space and power requirements within existing facilities are adequate to support installation of a spin balance machine.

The model showed that increased welding capability would reduce the BCM rate and TAT for the LPT (exhaust flame), CMB and AB modules. As discussed in Chapter III, repair of the LPT, CMB and AB modules is limited by non-availability of welding fixtures, jigs, and lack of titanium welder certifications. Storage space required for these additional fixtures and jigs is considered minimal and therefore additional facilities would not be necessary. As an example, AIMD Lemoore already has a titanium welding chamber on site in the work center and is awaiting welder training and certification.

Finally, the cost analysis provides evidence that cost savings would be achieved by expanding capabilities of the "selected" AIMDs. The level of savings achieved varies with the assumptions made for reduced AWP time and BCM actions in the simulation models. Total costs savings vary depending on whether Navy or civilian personnel are used to augment spin

balance and welding work centers and whether new or existing equipment is used (refer to Appendix F). The projected cost savings assuming civilian augmentation and new equipment are \$4,931,463.48 over a ten year period. If Navy personnel and existing equipment are used, then projected cost savings total \$5,962,692.50 over a ten year period.

C. RECOMMENDATIONS

The following recommendations are offered:

1. Expand the maintenance and repair capabilities of AIMDs Cecil Field and Lemoore. These expansions should include positioning of a spin balance machine in the Power Plants Division module repair work center. Further, increase the welding repair capability by providing additional training/certification of welders and necessary jigs and fixtures.
2. Perform a more detailed cost-benefit analysis using the results of this study to better analyze the cost effectiveness of expanding the repair capacity at the AIMD level. A further study could include analysis of the financial implications of expanding AIMD capabilities. Transferring selected repair capabilities from the NADEP to the AIMD involves the transfer of funds from depot maintenance to the flying hour program to augment funding the purchase or repair of aviation depot level repairables (AVDLRs). In the current system, modules are BCM'd without charge to the customer and repaired using depot maintenance funding. Components and sub-components incur an AVDLR charge paid for from the flying hour program.
3. Develop simulation models similar to the models in this thesis to study the impact at the component level. The component level simulation outcomes would provide detailed information on component TAT, WIP, and BCM actions resulting from increased repair capabilities at the AIMD. Because of time constraints and SIMAN software limitations (limits on lines of code and numbers of entities which can be processed within the system), this thesis was limited to studying impacts at the engine/module level. Development of separate simulation models for each of the six modules

would provide component TAT, WIP and BCM actions data. This data could be input into the model developed in this thesis. The simulated service times and BCM rates derived from the component level simulations would allow complete simulation of the F404 repair process within the AIMD.

4. Have the Naval Aviation Manpower Evaluation Center (NAVMEC) perform a manpower analysis to determine the proper manning requirement (civilian or Navy) for the spin balance technician billet and to determine whether a journeyman level civilian welder is warranted in the welding work center.

5. Conduct a study to determine the feasibility and cost effectiveness of installing a blade tip grinder/balancing machine similar to the one discussed in Chapter III.

6. Use simulation modeling to analyze the repair process of other aircraft power plant, hydraulic and avionic systems. The simulation model developed in this thesis can be applied to any repair process.

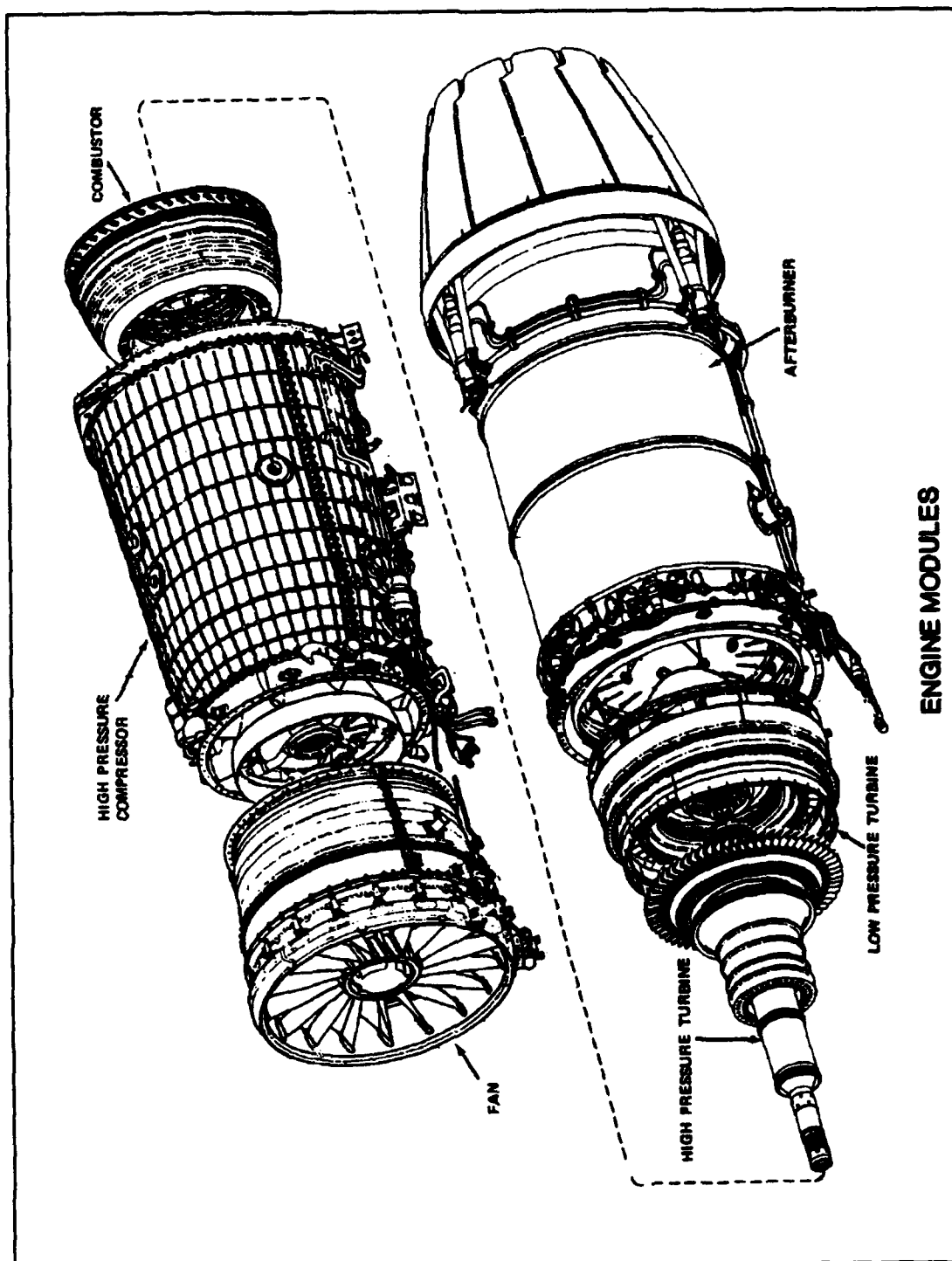
LIST OF REFERENCES

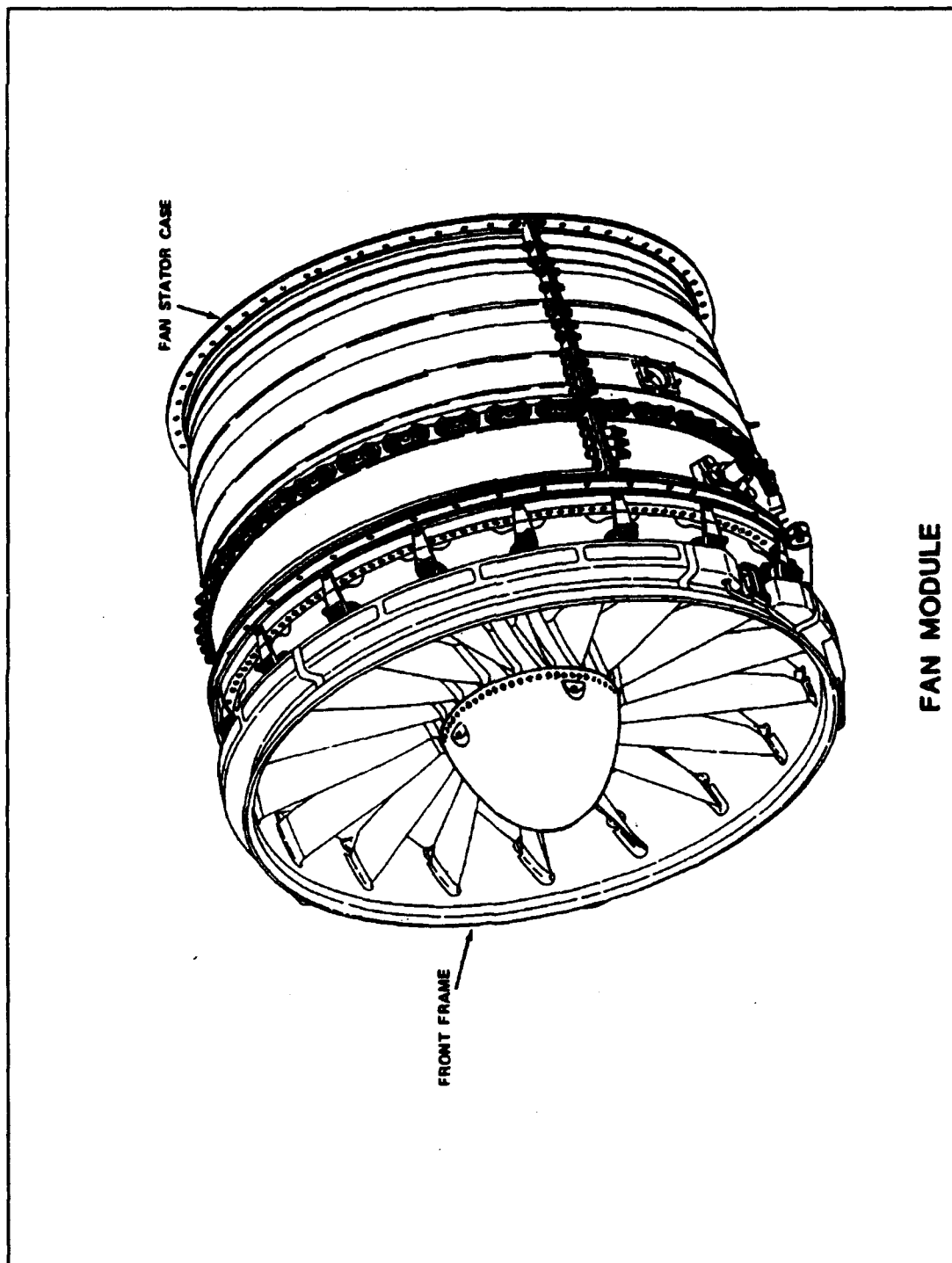
1. Naval Air Systems Command, NAVAIRNOTE 4700, Gas Turbine Engine Three Degrees of Intermediate Maintenance Activity Assignments, 23 October, 1992.
2. Department of Defense, "Defense Management Report Decision 908," Washington, D.C., 9 November 1989.
3. Atwood, D., Deputy Secretary of Defense Memorandum to Commander, Naval Air Systems Command: Subject:DMRD 908, 30 June 1990.
4. Department of Defense, Defense Depot Management Council, "Defense Depot Management Council Corporate Business Plan (FY 91-95)," Washington, D.C., November 1990.
5. Clinton, William, "State of the Union Address," Washington, D.C., 17 February 1993.
6. Department of the Navy, Chief of Naval Operations, OPNAVINST 4790.2E, *Naval Aviation Maintenance Program*, Volume I, January, 1989.
7. Embry, L. B., Moore, N. Y., Cave, J., LaBrune, F., *Depot Maintenance of Aviation Components: Contractor vs Organic Repair*, p.35, Rand Corporation, Santa Monica, California, 1985.
8. Naval Air Systems Command, Letter 4700:Ser AIR-433/044 to LCDR Stephen W. Bartlett, Subject: Proposed Thesis Topic, 2 February, 1993.
9. Blanchard, B.S., *Logistics Engineering and Management*, Prentice-Hall, Englewood Cliffs, New Jersey, 1992.
10. Department of the Navy, Chief of Naval Operations, OPNAVINST 4790.2E, *Naval Aviation Maintenance Program*, Volume III, January, 1989.
11. Department of the Navy, Chief of Naval Operations, "Manpower Authorization (OPNAV 1000/2 Rev. 9/82)," 17 February, 1992.
12. Interview between Robie, R., LCDR, USN, AIMD NAS Cecil Field, Florida, and the researchers, 7 April 1993.

13. Interview between Heintschel, A., LT, USN, AIMD NAS Lemoore, California, and the researchers, 24 March 1993.
14. Hamill, T., "F-18 Hornet," *Flight International*, 2 December 1978.
15. CNA Research Memorandum 90-137, *Supporting the F/A-18 F404-GE-400 Engine: Reliability, Maintainability, Readiness, and Cost*, by Mark B. Geis, 30 October 1990.
16. General Electric SEI-477, *GE Aircraft Engines F404-400 Training Guide*, Sixth Edition, October 1989.
17. General Electric, *F404-GE-400/402 Maintenance Plan, Revision J*, 3 June 1992.
18. Department of the Navy, Naval Air Systems Command, NAVAIRINST 4790.17, *Project RECOVER (Replace Engine Components Vice Engine Return)*, 3 September 1980.
19. Briefing by Rear Admiral Davidson, Aviation Supply Office, Naval Aviation Depot Corporate Board, ASO-NADEP PARTNERS, 23 February 1993.
20. Department of the Navy, Naval Air Systems Command, *Operation and Maintenance, Navy (O&MN) Budget Submission, "Aircraft Rework and Maintenance,"* September 1992.
21. Briefing by Captain Bert Coffman, NAVAIR 4106, *Depot/I-Level Engine Repair Funding*, November 1992.
22. Naval Air Systems Command, *Intermediate Maintenance Manual, A1-F404-MMI-210*, Vol. II, 29 March 1993.
23. Department of the Navy, Naval Air Systems Command, F404 SERD No. 0601, *Support Equipment Recommendation Data (SE)*, 6 July 1979.
24. Interview between Davidson, R., LCDR, USN, NADEP, Jacksonville, Florida, and the researchers, 7 April, 1993.
25. Interview between Kinzie, D., Engine Maintenance Center, General Electric Co., Ontario, California, and the researchers, 20 April, 1993.
26. Interview between Heffner, R., Machinist, NADEP, Jacksonville, Florida, and the researchers, 7 April, 1993.

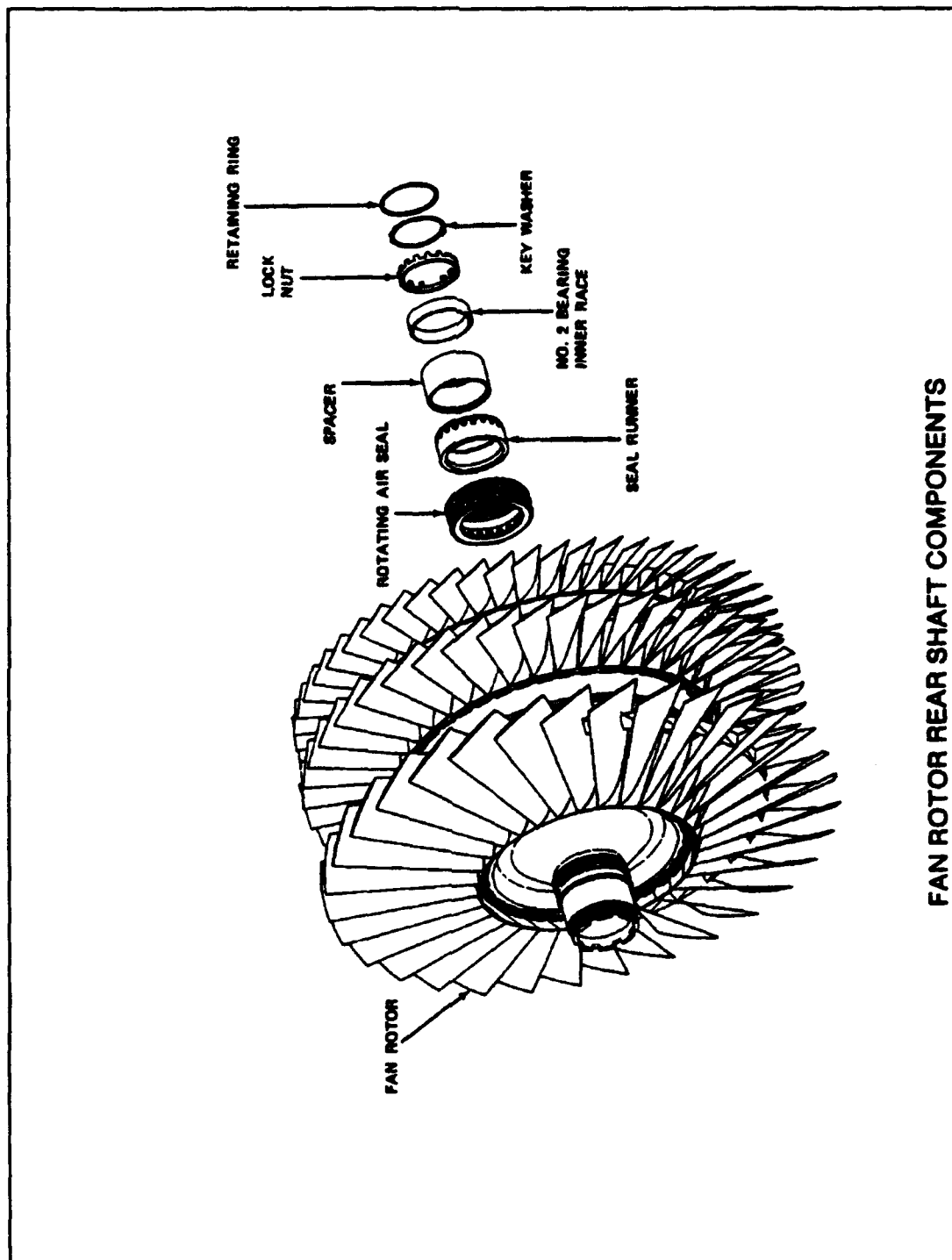
27. Interview between Cokeley, W.R., Facilities Process Engineer, NADEP, Jacksonville, Florida, and the researchers, 7 April, 1993.
28. Telephone conversation between Noel Lilly, Butler Newall Inc. and the researchers, 22 April 1993.
29. Telephone conversation between Dean Kunte, Code 612, NADEP, North Island, California, and the researchers, 22 April 1993.
30. Interview between Allen Standon, General Electric Company, and the researchers, 20 April 1993.
31. Pegden, C.D., Shannon, R.E., and Sadowski, R.P., *Introduction to Simulation Using SIMAN*, McGraw-Hill, New York, 1990.
32. Anderson, D.R., Sweeney, D.J., Williams, T.A., *An Introduction to Management Science, Quantitative Approaches to Decision Making*, 6th ed., West Publishing Company, St. Paul, Mn., 1991.
33. Law, A.M., and Kelton, W.D., *Simulation Modeling and Analysis*, McGraw-Hill, New York, 1991.
34. Department of the Navy, Chief of Naval Operations, OPNAVINST 1000.16G, *Manual of Navy Total Force Manpower Policies and Procedures*, 11 June 1990.
35. Naval Air Systems Command, *Aircraft Engine Management System Intermediate Level Receipt/Transfer Report*, FY92 NAS Cecil Field and NAS Lemoore, 27 April 1993.
36. Naval Air Systems Command, *Naval Aviation Logistics Data Analysis Report 572 Equipment Condition Analysis*, FY92 NAS Cecil Field and NAS Lemoore, 12 April 1993.
37. United States Government, *Economic Report of the President Transmitted to Congress January 1993*, January 1993.
38. Henderson, D. R., and Haga, W. J., *How To Account For Inflation When Taking Present Values*, NPS-54-90-020, U. S. Naval Postgraduate School, Monterey, California, September 1990.
39. Naval Aviation Depot Operations Center, *Memorandum to LCDR Paul Braun, Subj:F404 Data Requirements*, 8 April 1993.

APPENDIX A

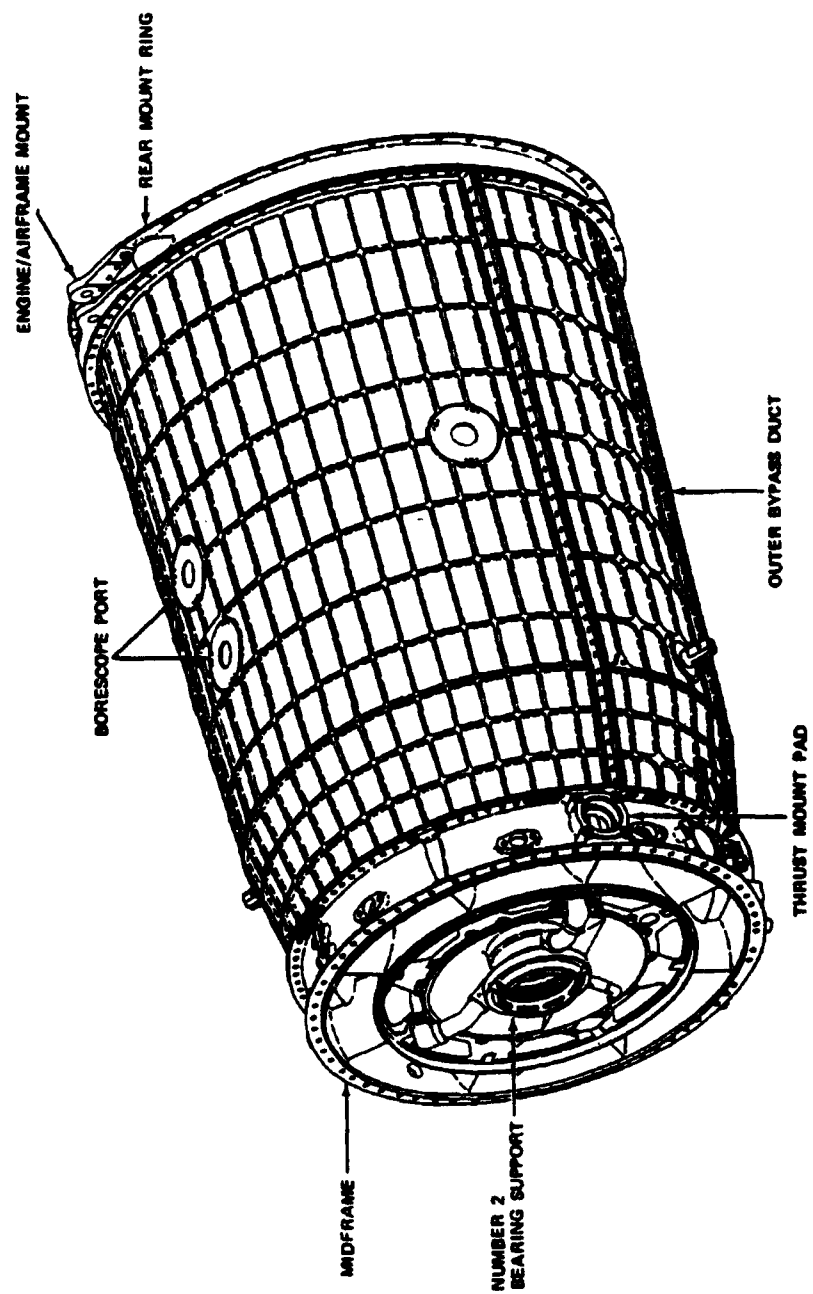




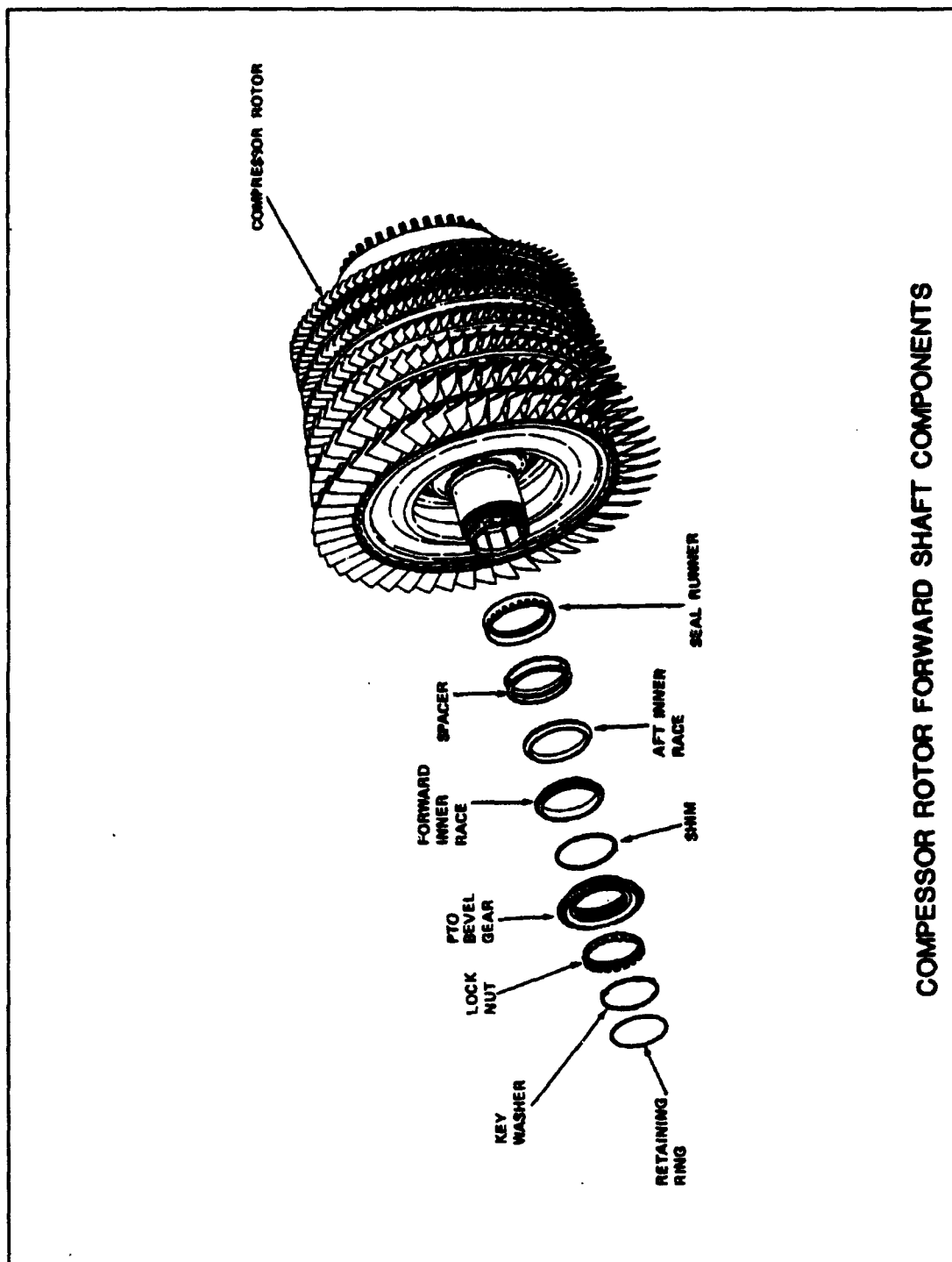
FAN MODULE



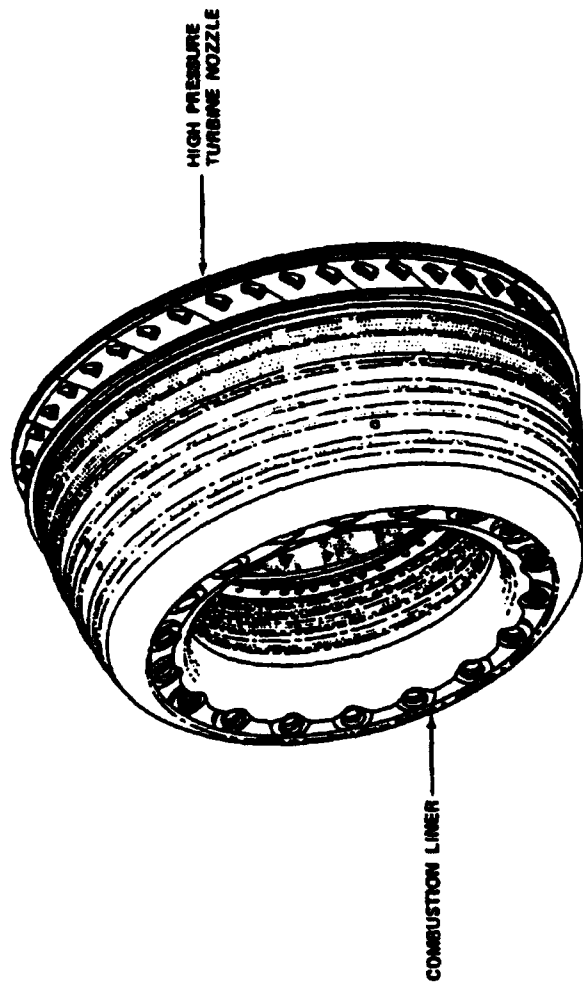
FAN ROTOR REAR SHAFT COMPONENTS



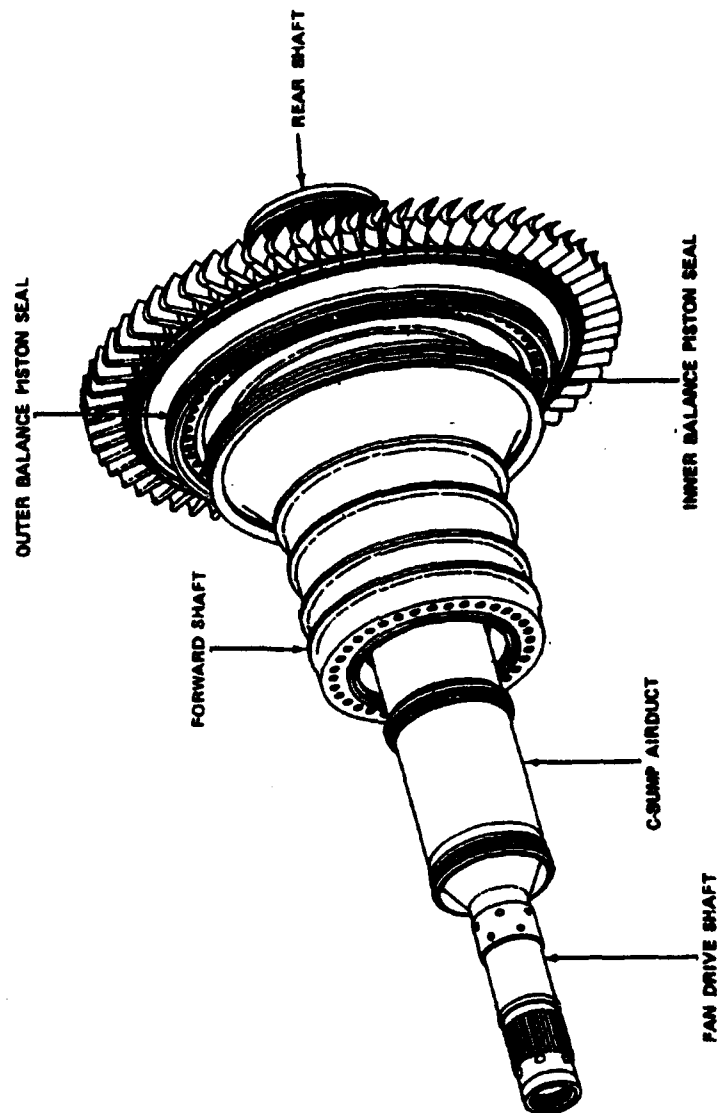
HIGH PRESSURE COMPRESSOR MODULE



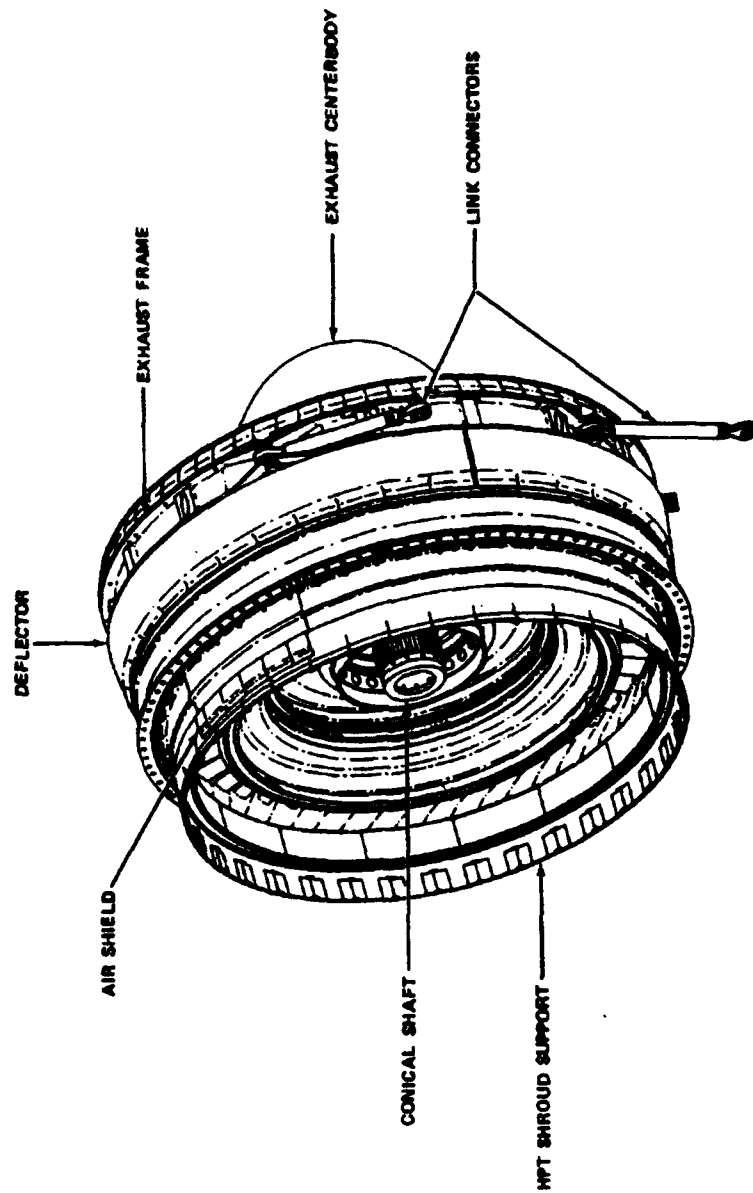
COMPRESSOR ROTOR FORWARD SHAFT COMPONENTS



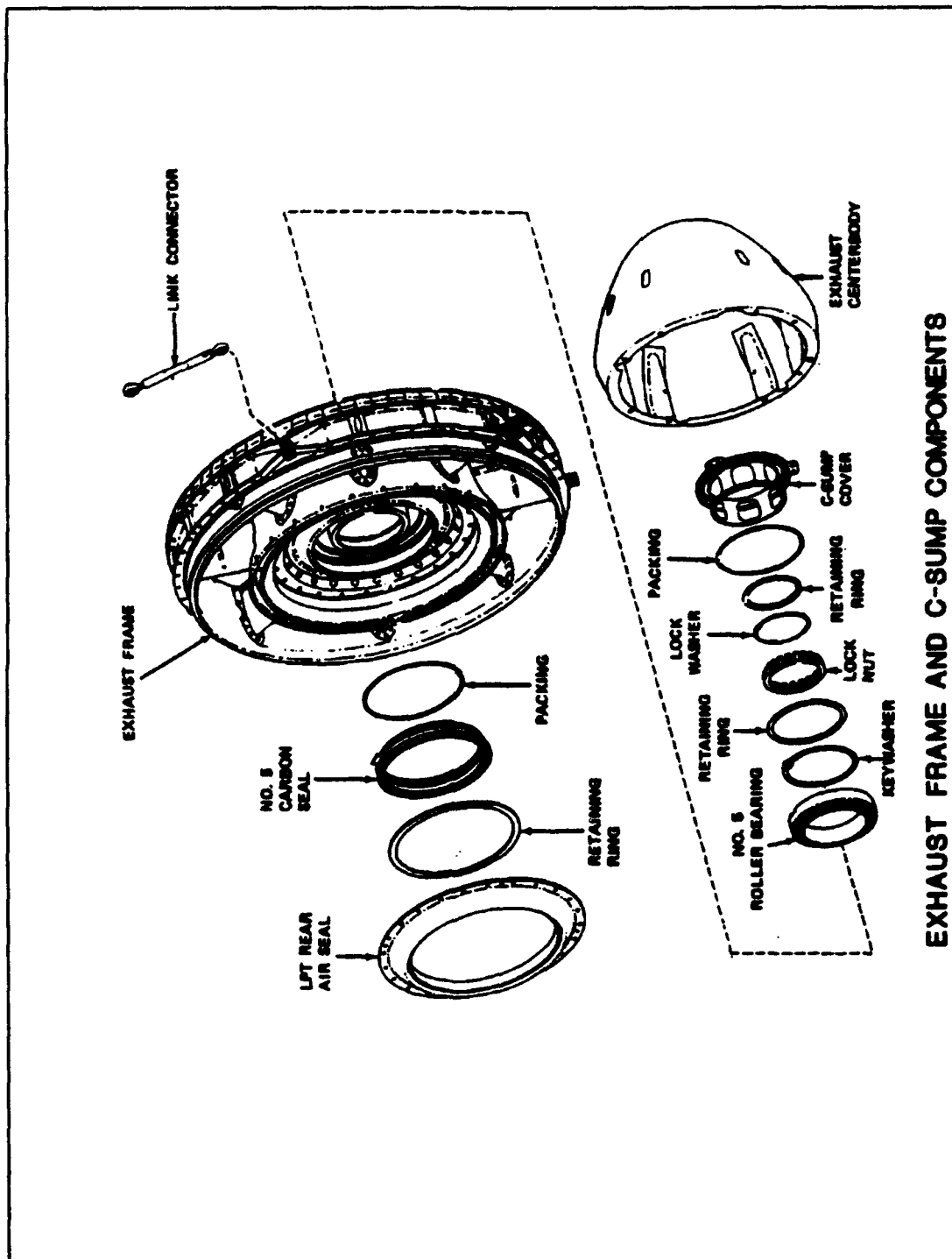
COMBUSTOR MODULE

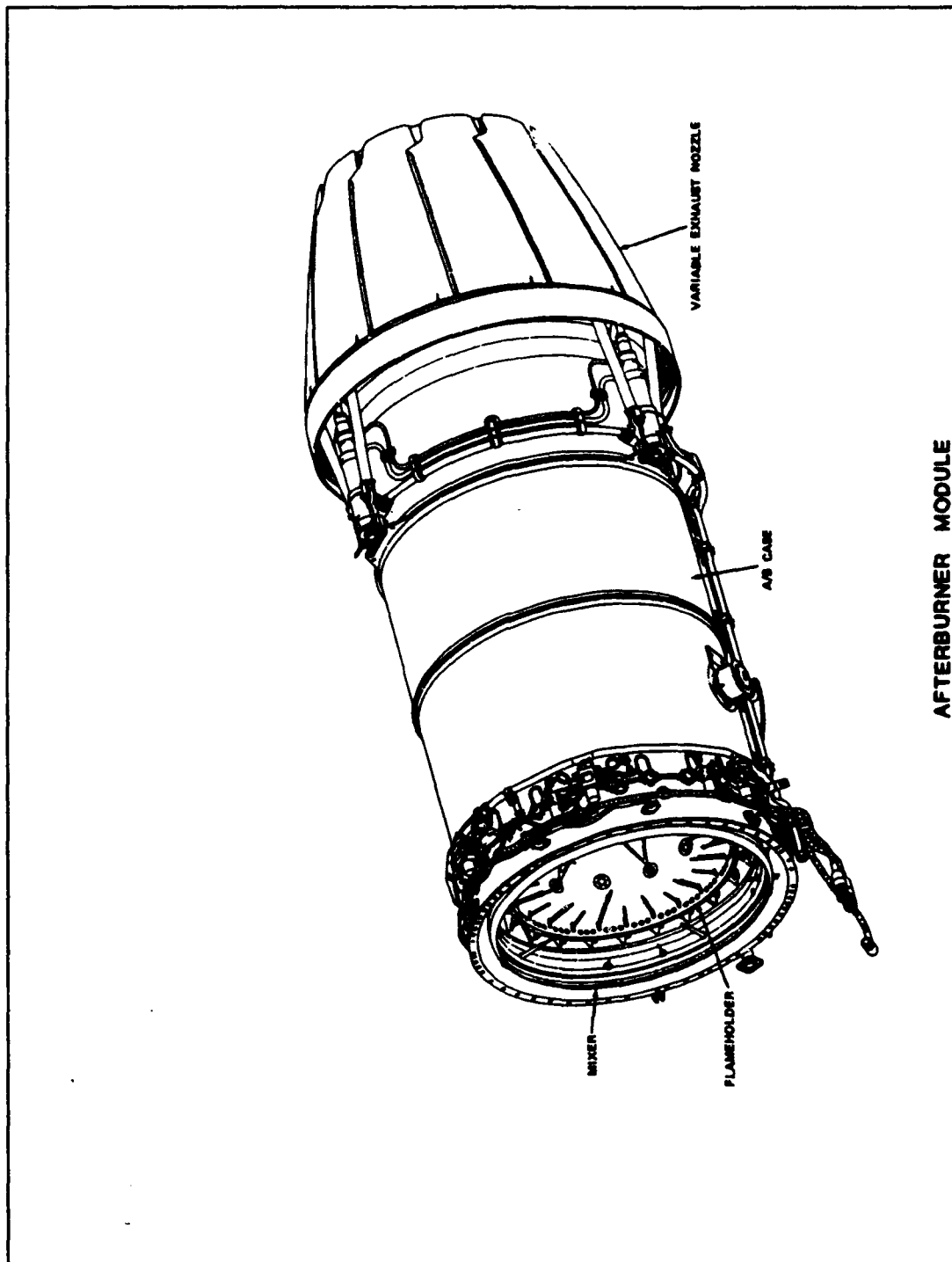


HIGH-PRESSURE TURBINE MODULE



LOW PRESSURE TURBINE MODULE





AFTERBURNER MODULE

APPENDIX B

F404 HPC Blades

Stage	Pre/Reg	P/N	NIIN	Price
1st	Pre	6066T88P02	01-289-6322	\$N/A
	Reg	6066T88P01	01-320-4326	\$63.00
2nd	Pre	6024T30P05	01-164-9581	\$62.00
	Reg	6024T30P01	01-164-9580	\$80.00
3rd	Std Reg	6072T13P01	01-318-1209	\$58.00
	Std Pre	6072T13P05	01-289-6321	\$N/A
	Reg LH	6072T13P03	01-314-8544	\$84.00
	Pre LH	6072T13P07	01-289-6320	\$N/A
	Reg RH	6072T13P04	01-316-7496	\$101.00
	Pre RH	6072T13P08	01-291-3020	\$75.00
	Spa Reg	6072T13P02	01-314-9622	\$85.00
	Spa Pre	6072T13P06	01-291-9501	\$90.00
	Reg RH	6024T32P08	01-129-3738	\$28.50
	Pre RH	6024T32P12	01-129-3784	\$34.00
4th	Reg RH	6054T79P08	01-291-3021	\$40.00
	Pre RH	6054T79P16	01-282-3579	\$34.00
	Reg LH	6024T32P07	01-129-3785	\$28.50
	Pre LH	6024T32P11	01-129-3786	\$30.50
	Reg LH	6054T79P07	01-291-9504	\$40.00
	Pre LH	6054T79P15	01-291-9505	\$40.00
	Spa Reg	6024T32P06	01-129-3787	\$25.00
	Std Pre	6024T32P09	01-129-3790	\$34.00
	Spa Pre	6054T79P14	01-296-7437	\$62.00
	Std Reg	6024T32P05	01-129-3789	\$30.50
	Std Reg	6054T79P05	01-291-9502	\$40.50
	Std Pre	6054T79P13	01-291-8392	\$40.50
	Reg RH	6024T33P08	01-131-4781	\$30.00
	Pre RH	6024T33P12	01-129-3777	\$40.50
5th	Reg LH	6024T33P07	01-129-3778	\$40.50
	Pre LH	6024T33P11	01-129-3779	\$29.50
	Std Reg	6024T33P05	01-129-3782	\$36.50
	Std Pre	6024T33P09	01-124-0915	\$33.50
	Spa Reg	6024T33P06	01-129-3780	\$39.50
	Spa Pre	6024T33P10	01-129-3781	\$23.00
	Reg RH	6024T34P04	01-139-7319	\$53.00
	Pre RH	6024T34P08	01-131-4777	\$37.00
6th	Reg LH	6024T34P03	01-139-7320	\$33.50
	Pre LH	6024T34P07	01-140-7657	\$42.00
	Std Reg	6024T34P01	01-131-4779	\$51.00
	Std Pre	6024T34P05	01-131-4780	\$32.50
	Spa Reg	6024T34P02	01-131-4778	\$34.50
	Spa Pre	6024T34P06	01-136-4345	\$36.50
	Reg RH	6024T35P04	01-131-4771	\$55.00
	Pre RH	6024T35P08	01-139-1318	\$43.00
7th	Reg LH	6024T35P03	01-131-4772	\$33.00
	Pre LH	6024T35P07	01-131-4773	\$29.50

F404 HPC Blades (Cont'd)

Stage	Pre/Reg	P/N	NIIN	Price
7th	Std Reg	6024T35P01	01-135-1520	\$48.50
	Std Pre	6024T35P05	01-131-4776	\$26.50
	Spa Reg	6024T35P02	01-131-4774	\$31.50
	Spa Pre	6024T35P06	01-131-4775	\$26.50

APPENDIX C

Model File-Current AIMD Cecil Field with Log Normal Distribution
BEGIN, Y, Existing Model of AIMD Cecil Field;

```
;
;      Simulation Model of F404 Engine Repair
;      written by
;      LCDR Paul F. Braun and LCDR Stephen W. Bartlett
;      U. S. Naval Postgraduate School
;      Monterey, California

CREATE:EXPO(28.0,1);create engine failures
ASSIGN: TimeIn=TNOW;
DELAY: LOGN(3.82,.76); engine removal
BRANCH,2:
    ALWAYS, Aircraft:
    ALWAYS, Engine;

;      SPARE ENGINE POOL QUEUE
Aircraft QUEUE,EngSpareQ; check the spare engine pool
SEIZE:EngSpare; seize the spare engine if available
;      otherwise wait in the EngSpareQ
TALLY:Time AC AWP, INT(TimeIn);
DELAY: LOGN(5.74,1.15); engine installation
TALLY:AC TAT, INT(TimeIn);
;      collect turnaround time (TAT)
;      fully mission capable (FMC)
COUNT:AC engines processed:DISPOSE;

;      ENGINE MAIN REPAIR CHANNEL QUEUE
Engine BRANCH,1:
    WITH,.0398,BcmEng:
    WITH,.9602,Engine1;
Engine1 QUEUE,MainChnl1Q; queue awaiting engine disassembly
SEIZE:WC41U; seize the eng disassy_assy chnl if
;      available
;      otherwise wait in queue
DELAY:LOGN(21.07,3.39); engine inspection,disassembly
RELEASE:WC41U; release the eng disassy_assy chnl
BRANCH,12:
    ALWAYS, Fan:
    ALWAYS, Hpt:
    ALWAYS, Lpt:
    ALWAYS, Hpc:
    ALWAYS, Cmb:
    ALWAYS, Afb:
    ALWAYS, Assy1:
    ALWAYS, Assy2:
    ALWAYS, Assy3:
    ALWAYS, Assy4:
    ALWAYS, Assy5:
```

```

        ALWAYS, Assy6;
Assy1    QUEUE,FanAssyQ;
        SEIZE,1:FanSpare;
Assy1a   QUEUE,FanAssy1Q:DETACH;
Assy2    QUEUE,HptAssyQ;
        SEIZE,1:HptSpare;
Assy2a   QUEUE,HptAssy1Q:DETACH;
Assy3    QUEUE,LptAssyQ;
        SEIZE,1:LptSpare;
Assy3a   QUEUE,LptAssy1Q:DETACH;
Assy4    QUEUE,HpcAssyQ;
        SEIZE,1:HpcSpare;
Assy4a   QUEUE,HpcAssy1Q:DETACH;
Assy5    QUEUE,CmbAssyQ;
        SEIZE,1:CmbSpare;
Assy5a   QUEUE,CmbAssy1Q:DETACH;
Assy6    QUEUE,AfbAssyQ;
        SEIZE,1:AfbSpare;
Assy6a   QUEUE,AfbAssy1Q:DETACH;
Assy7    MATCH,:Assy1a:Assy2a:Assy3a:Assy4a:Assy5a:Assy6a,Assy7;
        TALLY:Eng AWP,INT(TimeIn);
        QUEUE,MainChnl2Q;queue awaiting engine
;
                                accessory installation
        SEIZE:WC41U;seize the eng disassy_assy chnl if
                                available
;
                                otherwise wait in queue
        DELAY:LOGN(39.12,6.29); engine accessory installation
        RELEASE:WC41U:NEXT(TestC1); release the eng
                                disassy_assy chnl
TestC1   QUEUE,TestCellQ; queue awaiting test cell
        SEIZE:WC450; seize the test cell if available
;
                                otherwise wait in the queue
        DELAY:LOGN(3.02,.6);test cell operation
        RELEASE:WC450:NEXT(EngRpr); release the test cell
EngRpr   TALLY: Eng TAT,INT(TimeIn);
        COUNT: Engines repaired;
        RELEASE:EngSpare:DISPOSE;update the spare engine pool
BcmEng   COUNT:BcmEngines;
        DELAY:LOGN(220.8,44.16);delay awaiting return of Bcm
                                engine
        RELEASE:Engspare:DISPOSE; update the spare engine pool

Fan      BRANCH,1:
        WITH,.4485,FanRpr:
        WITH,.5515,FanSp; 55.15% of time fans don't require
                                repair
FanSp    DELAY:LOGN(1,.2);administrative delay
        RELEASE:FanSpare:DISPOSE;update the fan spare pool
FanRpr   BRANCH,1:
        WITH,.1333,BcmFan:
        WITH,.8667,FanRpr1;

```

```

FanRpr1    QUEUE, FanAwpQ;
           ASSIGN:TimeIn1=TNOW;
           SEIZE:Awp;
           DELAY:LOGN(792,158.4);awaiting parts
           TALLY:Fan AWP time,INT(TimeIn1);
           RELEASE:Awp;
           QUEUE,FanRepairQ1; queue awaiting fan repair
           SEIZE:WC414; seize module repair if available
           ASSIGN:TimeIn7=TNOW;
           DELAY:LOGN(22.18,15.85);fan WIP time
           TALLY:Fan WIP time,INT(TimeIn7);
           RELEASE:WC414;release the module repair channel
           TALLY:Fan TAT,INT(TimeIn);
           COUNT:Fans repaired;
           RELEASE:FanSpare:DISPOSE;update the fan spare pool
BcmFan     COUNT:BcmFans;
           DELAY:LOGN(297.6,59.52);delay for ACWT
           RELEASE:FanSpare:DISPOSE; update the fan spare pool

Hpt        BRANCH,1:
           WITH, .5914,HptRpr:
           WITH, .4086,HptSp;    40.86% of Hpts don't require
                                   repair
HptSp      DELAY:LOGN(1,.2);administrative delay time
           RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
HptRpr     BRANCH,1:
           WITH, .0955,BcmHpt:
           WITH, .9045,HptRpr1;
HptRpr1    QUEUE,HptAwpQ;
           ASSIGN:TimeIn2=TNOW;
           SEIZE:Awp;
           DELAY:LOGN(672,134.4);awaiting parts
           TALLY:Hpt AWP time,INT(TimeIn2);
           RELEASE:Awp;
           QUEUE,HptRepairQ1;queue awaiting Hpt repair
           SEIZE:WC414;seize module repair if available
           ASSIGN:TimeIn8=TNOW;
           DELAY:LOGN(18.38,5.22);Hpt WIP time
           TALLY:Hpt WIP time,INT(TimeIn8);
           RELEASE:WC414;release the module repair channel
           TALLY:Hpt TAT,INT(TimeIn);
           COUNT:Hpts repaired;
           RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
BcmHpt     COUNT:BcmHpts;
           DELAY:LOGN(316.8,63.36);delay for ACWT
           RELEASE:HptSpare:DISPOSE; update the Hpt spare pool

Lpt        BRANCH,1:
           WITH, .5216,LptRpr:
           WITH, .4784,LptSp;    47.84% of Lpts don't require
                                   repair

```

LptSp DELAY:LOGN(1,.2);administrative delay time
 RELEASE:LptSpare:DISPOSE; update the Lpt spare pool
 LptRpr BRANCH,1:
 WITH,.0573,BcmLpt:
 WITH,.9427,LptRpr1;
 LptRpr1 QUEUE,LptAwpQ;
 ASSIGN:TimeIn3=TNOW;
 SEIZE:Awp;
 DELAY:LOGN(504,100.8);awaiting parts
 TALLY:Lpt AWP time,INT(TimeIn3);
 RELEASE:Awp;
 QUEUE,LptRepairQ1;queue awaiting Lpt repair
 SEIZE:WC414;seize module repair if available
 ASSIGN:TimeIn9=TNOW;
 DELAY:LOGN(16.03,8.88);Lpt WIP time
 TALLY:Lpt WIP time,INT(TimeIn9);
 RELEASE:WC414;release the module repair channel
 TALLY:Lpt TAT,INT(TimeIn);
 COUNT:Lpts repaired;
 RELEASE:LptSpare:DISPOSE;update the Lpt spare pool
 BcmLpt COUNT:BcmLpts;
 DELAY:LOGN(184.8,36.96);delay for ACWT
 RELEASE:LptSpare:DISPOSE;update the Lpt spare pool

 Hpc BRANCH,1:
 WITH,.3854,HpcRpr:
 WITH,.6146,HpcSp; 61.46% of Hpcs don't require repair
 HpcSp DELAY:LOGN(1,.2);administrative delay time
 RELEASE:HpcSpare:DISPOSE; update the Hpc spare pool
 HpcRpr BRANCH,1:
 WITH,.0862,BcmHpc:
 WITH,.9138,HpcRpr1;
 HpcRpr1 QUEUE,HpcAwpQ;
 ASSIGN:TimeIn4=TNOW;
 SEIZE:Awp;
 DELAY:LOGN(744,148.8);awaiting parts
 TALLY:Hpc AWP time,INT(TimeIn4);
 RELEASE:Awp;
 QUEUE,HpcRepairQ1;queue awaiting Hpc repair
 SEIZE:WC414;seize module repair if available
 ASSIGN:TimeIn10=TNOW;
 DELAY:LOGN(43.87,70.35);Hpc WIP time
 TALLY:Hpc WIP time,INT(TimeIn10);
 RELEASE:WC414;release the module repair channel
 TALLY:Hpc TAT,INT(TimeIn);
 COUNT:Hpcs repaired;
 RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool
 BcmHpc COUNT:BcmHpcs;
 DELAY:LOGN(180,36);delay for ACWT
 RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool

Cmb BRANCH,1:
 WITH,.2857,CmbRpr:
 WITH,.7143,CmbSp; 71.43% of CmbS don't require
 repair
 CmbSp DELAY:LOGN(1,.2);administrative delay time
 RELEASE:CmbSpare:DISPOSE; update the Cmb spare pool
 CmbRpr BRANCH,1:
 WITH,.1163,BcmCmb:
 WITH,.8837,CmbRpr1;
 CmbRpr1 QUEUE,CmbAwpQ;
 ASSIGN:TimeIn5=TNOW;
 SEIZE:Awp;
 DELAY:LOGN(1656,331.2);awaiting parts
 TALLY:Cmb AWP time,INT(TimeIn5);
 RELEASE:Awp;
 QUEUE,CmbRepairQ1; queue awaiting Cmb repair
 SEIZE:WC414; seize module repair if available
 ASSIGN:TimeIn11=TNOW;
 DELAY:LOGN(9.71,1.22);Cmb WIP time
 TALLY:Cmb WIP time,INT(TimeIn11);
 RELEASE:WC414;release the module repair channel
 TALLY:Cmb TAT,INT(TimeIn);
 COUNT:CmbS repaired;
 RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool
 BcmCmb COUNT:BcmCmbS;
 DELAY:LOGN(278.4,55.68);delay for ACWT
 RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool

 Afb BRANCH,1:
 WITH,.6179,AfbRpr:
 WITH,.3821,AfbSp; 38.21% of Afbs don't require repair
 AfbSp DELAY:LOGN(1,.2);administrative delay time
 RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
 AfbRpr BRANCH,1:
 WITH,.0054,BcmAfb:
 WITH,.9946,AfbRpr1;
 AfbRpr1 QUEUE,AfbAwpQ;
 ASSIGN:TimeIn6=TNOW;
 SEIZE:Awp;
 DELAY:LOGN(384,76.8);awaiting parts
 TALLY:Afb AWP time,INT(TimeIn6);
 RELEASE:Awp;
 QUEUE,AfbRepairQ1; queue awaiting Afb repair
 SEIZE:WC413; seize the module repair channel
 ASSIGN:TimeIn12=TNOW;
 DELAY:LOGN(9.44,1.85);Afb repair time
 TALLY:Afb WIP time,INT(TimeIn12);
 RELEASE:WC413;release the module repair channel
 TALLY:Afb TAT,INT(TimeIn);
 COUNT:Afbs repaired;
 RELEASE:AfbSpare:DISPOSE;update the Afb spare pool

BcmAfb COUNT:BcmAfbs;
 DELAY:LOGN(237.6,47.52);delay for ACWT
 RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
END;

Experiment File-Current AIMD Cecil Field with Log Normal
Distribution

```
BEGIN;
PROJECT, Existing AIMD C.Field Model, P.Braun and S.Bartlett;
ATTRIBUTES:TimeIn:TimeIn1:TimeIn2:TimeIn3:TimeIn4:TimeIn5:
            TimeIn6:TimeIn7:TimeIn8:TimeIn9:TimeIn10:TimeIn11:
            TimeIn12;
QUEUES:EngSpareQ:MainChnl1Q:MainChnl2Q:TestCellQ:
        FanAssyQ:FanAssy1Q:HptAssyQ:HptAssy1Q:
        LptAssyQ:LptAssy1Q:HpcAssyQ:HpcAssy1Q:CmbAssyQ:
        CmbAssy1Q:AfbAssyQ:AfbAssy1Q:FanRepairQ1:FanAwpQ:
        HptRepairQ1:HptAwpQ:LptRepairQ1:LptAwpQ:HpcRepairQ1:
        HpcAwpQ:CmbRepairQ1:CmbAwpQ:AfbRepairQ1:AfbAwpQ;
RESOURCES: WC41U,4:! # of main engine disass_assy channels
            WC450,2: ! # of test cell channels
            WC414,3:! # of module repair channels
            WC413,1:! # of Afb repair channels
            EngSpare,12:! # of spare engines
            FanSpare,12: ! # of spare fans
            HptSpare,12:! # of spare Hpts
            LptSpare,12: ! # of spare Lpts
            HpcSpare,12:! # of spare Hpcs
            CmbSpare,10:! # of spare Cmbs
            AfbSpare,7:! # of spare Afbs
            Awp,1000;# of Awp channels
TALLIES:  Time AC AWP:
            AC TAT:
            Eng AWP:
            Eng TAT:
            Fan TAT:
            Hpc TAT:
            Hpt TAT:
            Lpt TAT:
            Cmb TAT:
            Afb TAT:
            Fan AWP time:
            Hpc AWP time:
            Hpt AWP time:
            Lpt AWP time:
            Cmb AWP time:
            Afb AWP time:
            Fan WIP time:
            Hpc WIP time:
            Hpt WIP time:
            Lpt WIP time:
            Cmb WIP time:
            Afb WIP time;
DSTAT:    (NR(WC41U)/4)*100, Eng disass_assy chnl use:
            (NR(WC450)/2)*100, Test cell chnl use:
            (NR(WC414)/3)*100, Module repair chnl use:
            (NR(WC413)/1)*100, Afb repair chnl use:
```

```

NQ(EngSpareQ), Num AC awtg eng:
NR(EngSpare), Avg EngSpare use:
NR(FanSpare), Avg FanSpare use:
NR(HpcSpare), Avg HpcSpare use:
NR(HptSpare), Avg HptSpare use:
NR(LptSpare), Avg LptSpare use:
NR(CmbSpare), Avg CmbSpare use:
NR(AfbSpare), Avg AfbSpare use;
COUNTERS: AC engines processed:Engines repaired:Fans repaired:
Hpts repaired:Lpts repaired:Hpcs repaired:Cmbs
repaired:Afbs repaired:BcmEngines:BcmFans:
BcmHpts:BcmLpts:BcmHpcs:
BcmCmbs:BcmAfbs;
SEEDS:1,434780; Seed for random number generation
REPLICATE, 10,0,8760,No,Yes,43800;
END;

```

```

Model File-Current AIMD Cecil Field with Triangular Distribution
BEGIN, Y, Existing Model of AIMD Cecil Field;
;
;       Simulation Model of F404 Engine Repair
;       written by
;       LCDR Paul F. Braun and LCDR Stephen W. Bartlett
;       U. S. Naval Postgraduate School
;       Monterey, California

CREATE:EXPO(28.0,1);create engine failures
ASSIGN: TimeIn=TNOW;
DELAY:  TRIA(2.87,3.82,5.73); engine removal
BRANCH,2:
    ALWAYS, Aircraft:
    ALWAYS, Engine;

;
Aircraft SPARE ENGINE POOL QUEUE
QUEUE,EngSpareQ; check the spare engine pool
SEIZE:EngSpare;  seize the spare engine if available
;                   otherwise wait in the EngSpareQ
TALLY:Time AC AWP, INT(TimeIn);
DELAY: TRIA(4.31,5.74,8.61); engine installation
TALLY:AC TAT, INT(TimeIn);
;                   collect turnaround time (TAT)
;                   fully mission capable (FMC)
COUNT:AC engines processed:DISPOSE;

;
Engine ENGINE MAIN REPAIR CHANNEL QUEUE
BRANCH,1:
    WITH,.0398,BcmEng:
    WITH,.9602,Engine1;
Engine1 QUEUE,MainChnl1Q; queue awaiting engine disassembly
SEIZE:WC41U; seize the eng disassy_assy chnl if
;                   available
;                   otherwise wait in queue
DELAY:TRIA(17.70,21.07,27.81); engine
;                   inspection,disassembly
RELEASE:WC41U; release the eng disassy_assy chnl
BRANCH,12:
    ALWAYS, Fan:
    ALWAYS, Hpt:
    ALWAYS, Lpt:
    ALWAYS, Hpc:
    ALWAYS, Cmb:
    ALWAYS, Afb:
    ALWAYS, Assy1:
    ALWAYS, Assy2:
    ALWAYS, Assy3:
    ALWAYS, Assy4:
    ALWAYS, Assy5:
    ALWAYS, Assy6;

```

```

Assy1      QUEUE, FanAssyQ;
           SEIZE, 1: FanSpare;
Assy1a     QUEUE, FanAssy1Q: DETACH;
Assy2      QUEUE, HptAssyQ;
           SEIZE, 1: HptSpare;
Assy2a     QUEUE, HptAssy1Q: DETACH;
Assy3      QUEUE, LptAssyQ;
           SEIZE, 1: LptSpare;
Assy3a     QUEUE, LptAssy1Q: DETACH;
Assy4      QUEUE, HpcAssyQ;
           SEIZE, 1: HpcSpare;
Assy4a     QUEUE, HpcAssy1Q: DETACH;
Assy5      QUEUE, CmbAssyQ;
           SEIZE, 1: CmbSpare;
Assy5a     QUEUE, CmbAssy1Q: DETACH;
Assy6      QUEUE, AfbAssyQ;
           SEIZE, 1: AfbSpare;
Assy6a     QUEUE, AfbAssy1Q: DETACH;
Assy7      MATCH, :Assy1a:Assy2a:Assy3a:Assy4a:Assy5a:Assy6a, Assy7;
           TALLY: Eng AWP, INT(TimeIn);
           QUEUE, MainChnl2Q; queue awaiting engine
;           accessory installation
           SEIZE: WC41U; seize the eng disassy_assy chnl if
           available
;           otherwise wait in queue
           DELAY: TRIA(32.87, 39.12, 51.64); engine accessory
           installation
           RELEASE: WC41U: NEXT(TestC1); release the eng
           disassy_assy chnl
TestC1     QUEUE, TestCellQ; queue awaiting test cell
           SEIZE: WC450; seize the test cell if available
;           otherwise wait in the queue
           DELAY: TRIA(2.27, 3.02, 4.53); test cell operation
           RELEASE: WC450: NEXT(EngRpr); release the test cell
EngRpr     TALLY: Eng TAT, INT(TimeIn);
           COUNT: Engines repaired;
           RELEASE: EngSpare: DISPOSE; update the spare engine pool
BcmEng     COUNT: BcmEngines;
           DELAY: TRIA(165.6, 220.8, 331.2); delay awaiting return of
           Bcm engine
           RELEASE: Engspare: DISPOSE; update the spare engine pool

Fan        BRANCH, 1:
           WITH, .4485, FanRpr:
           WITH, .5515, FanSp; 55.15% of time fans don't require
           repair
FanSp      DELAY: TRIA(.75, 1, 1.5); admin delay
           RELEASE: FanSpare: DISPOSE; update the fan spare pool
FanRpr     BRANCH, 1:
           WITH, .1333, BcmFan:
           WITH, .8667, FanRpr1;

```

```

FanRpr1    QUEUE, FanAwpQ;
           ASSIGN:TimeIn1=TNOW;
           SEIZE:Awp;
           DELAY:TRIA(594,792,1188);awaiting parts
           TALLY:Fan AWP time,INT(TimeIn1);
           RELEASE:Awp;
           QUEUE,FanRepairQ1; queue awaiting fan repair
           SEIZE:WC414; seize module repair if available
           ASSIGN:TimeIn7=TNOW;
           DELAY:TRIA(6.33,22.18,53.88);fan WIP time
           TALLY:Fan WIP time,INT(TimeIn7);
           RELEASE:WC414;release the module repair channel
           TALLY:Fan TAT,INT(TimeIn);
           COUNT:Fans repaired;
           RELEASE:FanSpare:DISPOSE;update the fan spare pool
BcmFan     COUNT:BcmFans;
           DELAY:TRIA(223.2,297.6,446.4);delay for ACWT
           RELEASE:FanSpare:DISPOSE; update the fan spare pool

Hpt        BRANCH,1:
           WITH, .5914,HptRpr:
           WITH, .4086,HptSp;      40.86% of Hpts don't require
                                   repair
HptSp      DELAY:TRIA(.75,1,1.5); admin delay
           RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
HptRpr     BRANCH,1:
           WITH, .0955,BcmHpt:
           WITH, .9045,HptRpr1;
HptRpr1    QUEUE,HptAwpQ;
           ASSIGN:TimeIn2=TNOW;
           SEIZE:Awp;
           DELAY:TRIA(504,672,1008);awaiting parts
           TALLY:Hpt AWP time,INT(TimeIn2);
           RELEASE:Awp;
           QUEUE,HptRepairQ1;queue awaiting Hpt repair
           SEIZE:WC414;seize module repair if available
           ASSIGN:TimeIn8=TNOW;
           DELAY:TRIA(13.16,18.38,28.82);Hpt WIP time
           TALLY:Hpt WIP time,INT(TimeIn8);
           RELEASE:WC414;release the module repair channel
           TALLY:Hpt TAT,INT(TimeIn);
           COUNT:Hpts repaired;
           RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
BcmHpt     COUNT:BcmHpts;
           DELAY:TRIA(237.6,316.8,475.2);delay for ACWT
           RELEASE:HptSpare:DISPOSE; update the Hpt spare pool

Lpt        BRANCH,1:
           WITH, .5216,LptRpr:
           WITH, .4784,LptSp;      47.84% of Lpts don't require
                                   repair

```

LptSp DELAY:TRIA(.75,1,1.5); admin delay
 RELEASE:LptSpare:DISPOSE; update the Lpt spare pool
 LptRpr BRANCH,1:
 WITH,.0573,BcmLpt:
 WITH,.9427,LptRpr1;
 LptRpr1 QUEUE,LptAwpQ;
 ASSIGN:TimeIn3=TNOW;
 SEIZE:Awp;
 DELAY:TRIA(378,504,756);awaiting parts
 TALLY:Lpt AWP time,INT(TimeIn3);
 RELEASE:Awp;
 QUEUE,LptRepairQ1;queue awaiting Lpt repair
 SEIZE:WC414;seize module repair if available
 ASSIGN:TimeIn9=TNOW;
 DELAY:TRIA(7.15,16.03,33.79);Lpt WIP time
 TALLY:Lpt WIP time,INT(TimeIn9);
 RELEASE:WC414;release the module repair channel
 TALLY:Lpt TAT,INT(TimeIn);
 COUNT:Lpts repaired;
 RELEASE:LptSpare:DISPOSE;update the Lpt spare pool
 BcmLpt COUNT:BcmLpts;
 DELAY:TRIA(138.6,184.8,277.2);delay for ACWT
 RELEASE:LptSpare:DISPOSE;update the Lpt spare pool

 Hpc BRANCH,1:
 WITH,.3854,HpcRpr:
 WITH,.6146,HpcSp; 61.46% of Hpcs don't require repair
 HpcSp DELAY:TRIA(.75,1,1.5); admin delay
 RELEASE:HpcSpare:DISPOSE; update the Hpc spare pool
 HpcRpr BRANCH,1:
 WITH,.0862,BcmHpc:
 WITH,.9138,HpcRpr1;
 HpcRpr1 QUEUE,HpcAwpQ;
 ASSIGN:TimeIn4=TNOW;
 SEIZE:Awp;
 DELAY:TRIA(558,744,1116);awaiting parts
 TALLY:Hpc AWP time,INT(TimeIn4);
 RELEASE:Awp;
 QUEUE,HpcRepairQ1;queue awaiting Hpc repair
 SEIZE:WC414;seize module repair if available
 ASSIGN:TimeIn10=TNOW;
 DELAY:TRIA(1.00,43.87,184.57);Hpc WIP time
 TALLY:Hpc WIP time,INT(TimeIn10);
 RELEASE:WC414;release the module repair channel
 TALLY:Hpc TAT,INT(TimeIn);
 COUNT:Hpcs repaired;
 RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool
 BcmHpc COUNT:BcmHpcs;
 DELAY:TRIA(135,180,270);delay for ACWT
 RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool

```

Cmb          BRANCH,1:
              WITH, .2857,CmbRpr:
              WITH, .7143,CmbSp; 71.43% of CmbS don't require
                                   repair
CmbSp        DELAY:TRIA(.75,1,1.5); admin delay
              RELEASE:CmbSpare:DISPOSE; update the Cmb spare pool
CmbRpr       BRANCH,1:
              WITH, .1163,BcmCmb:
              WITH, .8837,CmbRpr1;
CmbRpr1      QUEUE,CmbAwpQ;
              ASSIGN:TimeIn5=TNOW;
              SEIZE:Awp;
              DELAY:TRIA(1242,1656,2484);awaiting parts
              TALLY:Cmb AWP time,INT(TimeIn5);
              RELEASE:Awp;
              QUEUE,CmbRepairQ1; queue awaiting Cmb repair
              SEIZE:WC414; seize module repair if available
              ASSIGN:TimeIn11=TNOW;
              DELAY:TRIA(8.49,9.71,12.15);Cmb WIP time
              TALLY:Cmb WIP time,INT(TimeIn11);
              RELEASE:WC414;release the module repair channel
              TALLY:Cmb TAT,INT(TimeIn);
              COUNT:CmbS repaired;
              RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool
BcmCmb       COUNT:BcmCmbS
              DELAY:TRIA(208.8,278.4,417.6);delay for ACWT
              RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool

Afb          BRANCH,1:
              WITH, .6179,AfbRpr:
              WITH, .3821,AfbSp; 38.21% of Afbs don't require repair
AfbSp        DELAY:TRIA(.75,1,1.5); admin delay
              RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
AfbRpr       BRANCH,1:
              WITH, .0054,BcmAfb:
              WITH, .9946,AfbRpr1;
AfbRpr1      QUEUE,AfbAwpQ;
              ASSIGN:TimeIn6=TNOW;
              SEIZE:Awp;
              DELAY:TRIA(288,384,576);awaiting parts
              TALLY:Afb AWP time,INT(TimeIn6);
              RELEASE:Awp;
              QUEUE,AfbRepairQ1; queue awaiting Afb repair
              SEIZE:WC413; seize the module repair channel
              ASSIGN:TimeIn12=TNOW;
              DELAY:TRIA(7.59,9.44,13.14);Afb WIP time
              TALLY:Afb WIP time,INT(TimeIn12);
              RELEASE:WC413;release the module repair channel
              TALLY:Afb TAT,INT(TimeIn);
              COUNT:Afbs repaired;
              RELEASE:AfbSpare:DISPOSE;update the Afb spare pool

```


BcmAfb COUNT:BcmAfbs;
 DELAY:TRIA(178.2,237.6,356.4);delay for ACWT
 RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
END;

Experiment File-Current AIMD Cecil Field with Triangular Distribution

```

BEGIN;
PROJECT, Existing AIMD C.Field Model, P.Braun and S.Bartlett;
ATTRIBUTES:TimeIn:TimeIn1:TimeIn2:TimeIn3:TimeIn4:TimeIn5:
            TimeIn6:TimeIn7:TimeIn8:TimeIn9:TimeIn10:TimeIn11:
            TimeIn12;
QUEUES:EngSpareQ:MainChnl1Q:MainChnl2Q:TestCellQ:
        FanAssyQ:FanAssy1Q:HptAssyQ:HptAssy1Q:
        LptAssyQ:LptAssy1Q:HpcAssyQ:HpcAssy1Q:CmbAssyQ:
        CmbAssy1Q:AfbAssyQ:AfbAssy1Q:FanRepairQ1:FanAwpQ:
        HptRepairQ1:HptAwpQ:LptRepairQ1:LptAwpQ:HpcRepairQ1:
        HpcAwpQ:CmbRepairQ1:CmbAwpQ:AfbRepairQ1:AfbAwpQ;
RESOURCES: WC41U,4: ! # of main engine disass_assy channels
            WC450,2: ! # of test cell channels
            WC414,3: ! # of module repair channels
            WC413,1: ! # of Afb repair channels
            EngSpare,12: ! # of spare engines
            FanSpare,12: ! # of spare fans
            HptSpare,12: ! # of spare Hpts
            LptSpare,12: ! # of spare Lpts
            HpcSpare,12: ! # of spare Hpcs
            CmbSpare,10: ! # of spare Cmbs
            AfbSpare,7: ! # of spare Afbs
            Awp,1000; # of Awp channels
TALLIES:  Time AC AWP:
            AC TAT:
            Eng AWP:
            Eng TAT:
            Fan TAT:
            Hpc TAT:
            Hpt TAT:
            Lpt TAT:
            Cmb TAT:
            Afb TAT:
            Fan AWP time:
            Hpc AWP time:
            Hpt AWP time:
            Lpt AWP time:
            Cmb AWP time:
            Afb AWP time:
            Fan WIP time:
            Hpc WIP time:
            Hpt WIP time:
            Lpt WIP time:
            Cmb WIP time:
            Afb WIP time;
DSTAT:    (NR(WC41U)/4)*100, Eng disass_assy chnl use:
            (NR(WC450)/2)*100, Test cell chnl use:
            (NR(WC414)/3)*100, Module repair chnl use:
            (NR(WC413)/1)*100, Afb repair chnl use:

```

```

NQ(EngSpareQ), Num AC awtg eng:
NR(EngSpare), Avg EngSpare use:
NR(FanSpare), Avg FanSpare use:
NR(HpcSpare), Avg HpcSpare use:
NR(HptSpare), Avg HptSpare use:
NR(LptSpare), Avg LptSpare use:
NR(CmbSpare), Avg CmbSpare use:
NR(AfbSpare), Avg AfbSpare use;
COUNTERS: AC engines processed:Engines repaired:Fans repaired:
Hpts repaired:Lpts repaired:Hpcs repaired:Cmbs
repaired:Afbs repaired:BcmEngines:BcmFans:BcmHpts:
BcmLpts:BcmHpcs:
BcmCmbs:BcmAfbs;
SEEDS:1,434780; Seed for random number generation
REPLICATE, 10,0,8760,No,Yes,43800;
END;

```

Model File-Expanded AIMD Cecil Field with Log Normal Distribution
 BEGIN, Y, Proposed Model of AIMD Cecil Field;

```

;
;      Simulation Model of F404 Engine Repair
;      written by
;      LCDR Paul F. Braun and LCDR Stephen W. Bartlett
;      U. S. Naval Postgraduate School
;      Monterey, California

CREATE:EXPO(28.0,1);create engine failures
ASSIGN: TimeIn=TNOW;
DELAY: LOGN(3.82,.76); engine removal
BRANCH,2:
    ALWAYS, Aircraft:
    ALWAYS, Engine;

;      SPARE ENGINE POOL QUEUE
Aircraft QUEUE,EngSpareQ; check the spare engine pool
SEIZE:EngSpare; seize the spare engine if available
;      otherwise wait in the EngSpareQ
TALLY:Time AC AWP, INT(TimeIn);
DELAY: LOGN(5.74,1.15); engine installation
TALLY:AC TAT, INT(TimeIn);
;      collect turnaround time (TAT)
;      fully mission capable (FMC)
COUNT:AC engines processed:DISPOSE;

;      ENGINE MAIN REPAIR CHANNEL QUEUE
Engine BRANCH,1:
    WITH,.0398,BcmEng:
    WITH,.9602,Engine1;
Engine1 QUEUE,MainChnl1Q; queue awaiting engine disassembly
SEIZE:WC41U; seize the eng disassy_assy chnl if
;      available
;      otherwise wait in queue
DELAY:LOGN(21.07,3.39); engine inspection,disassembly
RELEASE:WC41U; release the eng disassy_assy chnl
BRANCH,12:
    ALWAYS, Fan:
    ALWAYS, Hpt:
    ALWAYS, Lpt:
    ALWAYS, Hpc:
    ALWAYS, Cmb:
    ALWAYS, Afb:
    ALWAYS, Assy1:
    ALWAYS, Assy2:
    ALWAYS, Assy3:
    ALWAYS, Assy4:
    ALWAYS, Assy5:
    ALWAYS, Assy6;
Assy1 QUEUE,FanAssyQ;

```

```

Assy1a    SEIZE,1:FanSpare;
Assy2     QUEUE,FanAssy1Q:DETACH;
Assy2a    SEIZE,1:HptSpare;
Assy3     QUEUE,HptAssy1Q:DETACH;
Assy3a    SEIZE,1:LptSpare;
Assy4     QUEUE,LptAssy1Q:DETACH;
Assy4a    SEIZE,1:HpcSpare;
Assy5     QUEUE,HpcAssy1Q:DETACH;
Assy5a    SEIZE,1:CmbSpare;
Assy6     QUEUE,CmbAssy1Q:DETACH;
Assy6a    SEIZE,1:AfbSpare;
Assy7     QUEUE,AfbAssy1Q:DETACH;
Assy7     MATCH,:Assy1a:Assy2a:Assy3a:Assy4a:Assy5a:Assy6a,Assy7;
Assy7     TALLY:Eng AWP,INT(TimeIn);
Assy7     QUEUE,MainChnl2Q;queue awaiting engine
;         accessory installation
SEIZE:WC41U;seize the eng disassy_assy chnl if
;         available
;         otherwise wait in queue
DELAY:LOGN(39.12,6.29); engine accessory installation
RELEASE:WC41U:NEXT(TestC1); release the eng
;         disassy_assy chnl
TestC1    QUEUE,TestCellQ; queue awaiting test cell
TestC1    SEIZE:WC450; seize the test cell if available
;         otherwise wait in the queue
DELAY:LOGN(3.02,.6);test cell operation
RELEASE:WC450:NEXT(EngRpr); release the test cell
EngRpr    TALLY: Eng TAT,INT(TimeIn);
EngRpr    COUNT: Engines repaired;
EngRpr    RELEASE:EngSpare:DISPOSE;update the spare engine pool
BcmEng    COUNT:BcmEngines;
BcmEng    DELAY:LOGN(220.8,44.16);delay awaiting return of Bcm
;         engine
BcmEng    RELEASE:Engspare:DISPOSE; update the spare engine pool

Fan       BRANCH,1:
Fan       WITH,.4485,FanRpr:
Fan       WITH,.5515,FanSp; 55.15% of time fans don't require
;         repair
FanSp     DELAY:LOGN(1,.2); admin delay
FanSp     RELEASE:FanSpare:DISPOSE;update the fan spare pool
FanRpr    BRANCH,1:
FanRpr    WITH,.0866,BcmFan:
FanRpr    WITH,.9134,FanRpr1;
FanRpr1   QUEUE,FanAwpQ;

```

```

ASSIGN:TimeIn1=TNOW;
SEIZE:Awp;
DELAY:LOGN(673,134.6);awaiting parts
TALLY:Fan AWP time,INT(TimeIn1);
RELEASE:Awp;
QUEUE,FanRepairQ1; queue awaiting fan repair
SEIZE:WC414; seize module repair if available
ASSIGN:TimeIn7=TNOW;
DELAY:LOGN(22.18,15.85);fan WIP time
TALLY:Fan WIP time,INT(TimeIn7);
RELEASE:WC414:NEXT(Spnbalfan);release the module repair
                                channel
FanRpr2  TALLY:Fan TAT,INT(TimeIn);
COUNT:Fans repaired;
RELEASE:FanSpare:DISPOSE;update the fan spare pool
BcmFan   COUNT:BcmFans;
DELAY:LOGN(297.6,59.52);delay for ACWT
RELEASE:FanSpare:DISPOSE; update the fan spare pool
Spnbalfan  BRANCH,1:
            WITH,.0865,Spnbalf:
            WITH,.9135,FanRpr2;91.35% of time fan does not
                                require balancing
Spnbalf   QUEUE,Spnbalfan1Q; queue awaiting fan balance
SEIZE:WC415;seize the spnbal repair chnl
DELAY:LOGN(2.0,.4);delay for spnbal
COUNT:Fansbal;
RELEASE:WC415:NEXT(FanRpr2); release the spnbal repair
                                chnl

Hpt       BRANCH,1:
            WITH,.5914,HptRpr:
            WITH,.4086,HptSp;    40.86% of Hpts don't require
                                repair
HptSp     DELAY:LOGN(1,.2); admin delay
RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
HptRpr    BRANCH,1:
            WITH,.0478,BcmHpt:
            WITH,.9522,HptRpr1;
HptRpr1   QUEUE,HptAwpQ;
ASSIGN:TimeIn2=TNOW;
SEIZE:Awp;
DELAY:LOGN(571,114.2);awaiting parts
TALLY:Hpt AWP time,INT(TimeIn2);
RELEASE:Awp;
QUEUE,HptRepairQ1;queue awaiting Hpt repair
SEIZE:WC414;seize module repair if available
ASSIGN:TimeIn8=TNOW;
DELAY:LOGN(18.38,5.22);Hpt WIP time
TALLY:Hpt WIP time,INT(TimeIn8);
RELEASE:WC414:NEXT(SpnbalHpt);release the module repair
                                channel

```

HptRpr2 TALLY:Hpt TAT,INT(TimeIn);
 COUNT:Hpts repaired;
 RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
 BcmHpt COUNT:BcmHpts;
 DELAY:LOGN(316.8,63.36);delay for ACWT
 RELEASE:HptSpare:DISPOSE; update the Hpt spare pool
 SpnbalHpt BRANCH,1:
 WITH,.0478,SpnbalH:
 WITH,.9522,HptRpr2; 95.22% of time Hpt does not
 require balancing
 SpnbalH QUEUE,SpnbalHpt1Q; queue awaiting Hpt spnbal
 SEIZE:WC415; seize the Spnbal repair chnl
 DELAY:LOGN(2.0,.4); delay for spnbal
 COUNT:Hptsbal;
 RELEASE:WC415:NEXT(HptRpr2); release the Spnbal repair
 chnl

 Lpt BRANCH,1:
 WITH,.5216,LptRpr:
 WITH,.4784,LptSp; 47.84% of Lpts don't require
 repair
 LptSp DELAY:LOGN(1,.2); admin delay
 RELEASE:LptSpare:DISPOSE; update the Lpt spare pool
 LptRpr BRANCH,1:
 WITH,.0281,BcmLpt:
 WITH,.9719,LptRpr1;
 LptRpr1 QUEUE,LptAwpQ;
 ASSIGN:TimeIn3=TNOW;
 SEIZE:Awp;
 DELAY:LOGN(428,85.6);awaiting parts
 TALLY:Lpt AWP time,INT(TimeIn3);
 RELEASE:Awp;
 QUEUE,LptRepairQ1;queue awaiting Lpt repair
 SEIZE:WC414;seize module repair if available
 ASSIGN:TimeIn10=TNOW;
 DELAY:LOGN(20.04,11.1);Lpt WIP time
 TALLY:Lpt WIP time,INT(TimeIn10);
 RELEASE:WC414:NEXT(SpnbalLpt);release the module repair
 channel

 LptRpr2 TALLY:Lpt TAT,INT(TimeIn);
 COUNT:Lpts repaired;
 RELEASE:LptSpare:DISPOSE;update the Lpt spare pool
 BcmLpt COUNT:BcmLpts;
 DELAY:LOGN(184.8,36.96);delay for ACWT
 RELEASE:LptSpare:DISPOSE;update the Lpt spare pool
 SpnbalLpt BRANCH,1:
 WITH,.0172,SpnbalL:
 WITH,.9828,LptRpr2; 98.28% of time Lpt does not
 require balancing
 SpnbalL QUEUE,SpnbalLpt1Q;
 SEIZE:WC415;seize the Spnbal repair chnl

```

DELAY:LOGN(2,.4); delay for Spnbal
COUNT:Lptsbal;
RELEASE:WC415:NEXT(LptRpr2); release the Spnbal repair
                                chnl

Hpc      BRANCH,1:
          WITH,.3854,HpcRpr:
          WITH,.6146,HpcSp; 61.46% of Hpcs don't require repair
HpcSp    DELAY:LOGN(1,.2); admin delay
          RELEASE:HpcSpare:DISPOSE; update the Hpc spare pool
HpcRpr   BRANCH,1:
          WITH,.0259,BcmHpc:
          WITH,.9741,HpcRpr1;
HpcRpr1  QUEUE,HpcAwpQ;
          ASSIGN:TimeIn4=TNOW;
          SEIZE:Awp;
          DELAY:LOGN(632,126.4);awaiting parts
          TALLY:Hpc AWP time,INT(TimeIn4);
          RELEASE:Awp;
          QUEUE,HpcRepairQ1;queue awaiting Hpc repair
          SEIZE:WC414;seize module repair if available
          ASSIGN:TimeIn10=TNOW;
          DELAY:LOGN(43.87,70.35);Hpc WIP time
          TALLY:Hpc WIP time,INT(TimeIn10);
          RELEASE:WC414:NEXT(SpnbalHpc);release the module repair
                                channel

HpcRpr2  TALLY:Hpc TAT,INT(TimeIn);
          COUNT:Hpcs repaired;
          RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool
BcmHpc   COUNT:BcmHpcs;
          DELAY:LOGN(180,36);delay for ACWT
          RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool
SpnbalHpc BRANCH,1:
          WITH,.0603,SpnbalHp:
          WITH,.9397,HpcRpr2; 93.97% of time Hpc does not
                                require balancing
SpnbalHp  QUEUE,SpnbalHpc1Q;
          SEIZE:WC415;seize the Spnbal repair chnl
          DELAY:LOGN(4,.8); delay for Spnbal
          COUNT:Hpcsbal;
          RELEASE:WC415:NEXT(HpcRpr2); release the Spnbal repair
                                chnl

Cmb      BRANCH,1:
          WITH,.2857,CmbRpr:
          WITH,.7143,CmbSp; 71.43% of CmbS don't require
                                repair
CmbSp    DELAY:LOGN(1,.2); admin delay
          RELEASE:CmbSpare:DISPOSE; update the Cmb spare pool
CmbRpr   BRANCH,1:
          WITH,.0814,BcmCmb:

```



```

CmbRpr1      WITH, .9186, CmbRpr1;
              QUEUE, CmbAwpQ;
              ASSIGN:TimeIn5=TNOW;
              SEIZE:Awp;
              DELAY:LOGN(1408,281.6);awaiting parts
              TALLY:Cmb AWP time,INT(TimeIn5);
              RELEASE:Awp;
              QUEUE,CmbRepairQ1; queue awaiting Cmb repair
              SEIZE:WC414; seize module repair if available
              ASSIGN:TimeIn11=TNOW;
              DELAY:LOGN(12.14,1.53);Cmb WIP time
              TALLY:Cmb WIP time,INT(TimeIn11);
              RELEASE:WC414;release the module repair channel
              TALLY:Cmb TAT,INT(TimeIn);
              COUNT:Cmbs repaired;
              RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool
BcmCmb      COUNT:BcmCmbs;
              DELAY:LOGN(278.4,55.68);delay for ACWT
              RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool

Afb          BRANCH,1:
              WITH, .6179, AfbRpr:
              WITH, .3821, AfbSp; 38.21% of Afbs don't require repair
AfbSp      DELAY:LOGN(1,.2); admin delay
              RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
AfbRpr      BRANCH,1:
              WITH, .0038, BcmAfb:
              WITH, .9962, AfbRpr1;
AfbRpr1     QUEUE, AfbAwpQ;
              ASSIGN:TimeIn6=TNOW;
              SEIZE:Awp;
              DELAY:LOGN(326,65.2);awaiting parts
              TALLY:Afb AWP time,INT(TimeIn6);
              RELEASE:Awp;
              QUEUE,AfbRepairQ1; queue awaiting Afb repair
              SEIZE:WC413; seize the module repair channel
              ASSIGN:TimeIn12=TNOW;
              DELAY:LOGN(11.80,2.31);Afb WIP time
              TALLY:Afb WIP time,INT(TimeIn12);
              RELEASE:WC413;release the module repair channel
              TALLY:Afb TAT,INT(TimeIn);
              COUNT:Afbs repaired;
              RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
BcmAfb      COUNT:BcmAfbs;
              DELAY:LOGN(237.6,47.52);delay for ACWT
              RELEASE:AfbSpare:DISPOSE;update the Afb spare pool

END;

```

```

Experiment File-Expanded AIMD Cecil Field with Log Normal
Distribution
BEGIN;
PROJECT, Proposed AIMD C.Field Model, P.Braun and S.Bartlett;
ATTRIBUTES:TimeIn:TimeIn1:TimeIn2:TimeIn3:TimeIn4:TimeIn5:
           TimeIn6:TimeIn7:TimeIn8:TimeIn9:TimeIn10:TimeIn11:
           TimeIn12;
QUEUES:EngSpareQ:MainChnl1Q:MainChnl2Q:TestCellQ:
       FanAssyQ:FanAssy1Q:HptAssyQ:HptAssy1Q:
       LptAssyQ:LptAssy1Q:HpcAssyQ:HpcAssy1Q:CmbAssyQ:
       CmbAssy1Q:AfbAssyQ:AfbAssy1Q:FanRepairQ1:FanAwpQ:
       HptRepairQ1:HptAwpQ:LptRepairQ1:LptAwpQ:HpcRepairQ1:
       HpcAwpQ:CmbRepairQ1:CmbAwpQ:AfbRepairQ1:AfbAwpQ:
       SpnbalFan1Q:SpnbalHpt1Q:SpnbalLpt1Q:SpnbalHpc1Q;
RESOURCES: WC41U,4:!! # of main engine disass_assy channels
           WC450,2: ! # of test cell channels
           WC414,3:!! # of module repair channels
           WC413,1:!! # of Afb repair channels
           WC415,1:!! # of Spnbal repair channels
           EngSpare,12:!! # of spare engines
           FanSpare,12: ! # of spare fans
           HptSpare,12:!! # of spare Hpts
           LptSpare,12: ! # of spare Lpts
           HpcSpare,12:!! # of spare Hpcs
           CmbSpare,10:!! # of spare Cmbs
           AfbSpare,7:!! # of spare Afbs
           Awp,1000;# of Awp channels
TALLIES:  Time AC AWP:
           AC TAT:
           Eng AWP:
           Eng TAT:
           Fan TAT:
           Hpc TAT:
           Hpt TAT:
           Lpt TAT:
           Cmb TAT:
           Afb TAT:
           Fan AWP time:
           Hpc AWP time:
           Hpt AWP time:
           Lpt AWP time:
           Cmb AWP time:
           Afb AWP time:
           Fan WIP time:
           Hpc WIP time:
           Hpt WIP time:
           Lpt WIP time:
           Cmb WIP time:
           Afb WIP time;
DSTAT:   (NR(WC41U)/4)*100, Eng disass_assy chnl use:
           (NR(WC450)/2)*100, Test cell chnl use:

```

```

(NR(WC414)/3)*100, Module repair chnl use:
(NR(WC413)/1)*100, Afb repair chnl use:
(NR(WC415)/1)*100, Spnbal repair chnl use:
NQ(EngSpareQ), Num AC awtg eng:
NR(EngSpare), Avg EngSpare use:
NR(FanSpare), Avg FanSpare use:
NR(HpcSpare), Avg HpcSpare use:
NR(HptSpare), Avg HptSpare use:
NR(LptSpare), Avg LptSpare use:
NR(CmbSpare), Avg CmbSpare use:
NR(AfbSpare), Avg AfbSpare use;
COUNTERS: AC engines processed:Engines repaired:Fans repaired:
Hpts repaired:Lpts repaired:Hpcs repaired:Cmbs
repaired:Afbs repaired:BcmEngines:BcmFans:BcmHpts:
BcmLpts:BcmHpcs:
BcmCmbs:BcmAfbs:Fansbal:Hptsbal:Lptsbal:Hpcsbal;
SEEDS:1,434780; Seed for random number generation
REPLICATE, 10,0,8760,No,Yes,43800;
END;

```

Model File-Expanded AIMD Cecil Field with Triangular Distribution
BEGIN, Y, Proposed Model of AIMD Cecil Field;

```
;
;      Simulation Model of F404 Engine Repair
;      written by
;      LCDR Paul F. Braun and LCDR Stephen W. Bartlett
;      U. S. Naval Postgraduate School
;      Monterey, California

CREATE:EXPO(28.0,1);create engine failures
ASSIGN: TimeIn=TNOW;
DELAY:  TRIA(2.87,3.82,5.73); engine removal
BRANCH,2:
    ALWAYS, Aircraft:
    ALWAYS, Engine;

;      SPARE ENGINE POOL QUEUE
Aircraft QUEUE,EngSpareQ; check the spare engine pool
SEIZE:EngSpare;  seize the spare engine if available
;              otherwise wait in the EngSpareQ
TALLY:Time AC AWP, INT(TimeIn);
DELAY: TRIA(4.31,5.74,8.61); engine installation
TALLY:AC TAT, INT(TimeIn);
;              collect turnaround time (TAT)
;              fully mission capable (FMC)
COUNT:AC engines processed:DISPOSE;

;      ENGINE MAIN REPAIR CHANNEL QUEUE
Engine BRANCH,1:
    WITH,.0398,BcmEng:
    WITH,.9602,Engine1;
Engine1 QUEUE,MainChnl1Q; queue awaiting engine disassembly
SEIZE:WC41U; seize the eng disassy_assy chnl if
;              available
;              otherwise wait in queue
DELAY:TRIA(17.70,21.07,27.81); engine
;              inspection,disassembly
RELEASE:WC41U; release the eng disassy_assy chnl
BRANCH,12:
    ALWAYS, Fan:
    ALWAYS, Hpt:
    ALWAYS, Lpt:
    ALWAYS, Hpc:
    ALWAYS, Cmb:
    ALWAYS, Afb:
    ALWAYS, Assy1:
    ALWAYS, Assy2:
    ALWAYS, Assy3:
    ALWAYS, Assy4:
    ALWAYS, Assy5:
    ALWAYS, Assy6;
```

```

Assy1      QUEUE, FanAssyQ;
           SEIZE, 1: FanSpare;
Assy1a     QUEUE, FanAssy1Q: DETACH;
Assy2      QUEUE, HptAssyQ;
           SEIZE, 1: HptSpare;
Assy2a     QUEUE, HptAssy1Q: DETACH;
Assy3      QUEUE, LptAssyQ;
           SEIZE, 1: LptSpare;
Assy3a     QUEUE, LptAssy1Q: DETACH;
Assy4      QUEUE, HpcAssyQ;
           SEIZE, 1: HpcSpare;
Assy4a     QUEUE, HpcAssy1Q: DETACH;
Assy5      QUEUE, CmbAssyQ;
           SEIZE, 1: CmbSpare;
Assy5a     QUEUE, CmbAssy1Q: DETACH;
Assy6      QUEUE, AfbAssyQ;
           SEIZE, 1: AfbSpare;
Assy6a     QUEUE, AfbAssy1Q: DETACH;
           MATCH, :Assy1a:Assy2a:Assy3a:Assy4a:Assy5a:Assy6a, Assy7;
Assy7      TALLY: Eng AW, INT(TimeIn);
           QUEUE, MainChnl2Q; queue awaiting engine
;                                     accessory installation
           SEIZE: WC41U; seize the eng disassy_assy chnl if
                                     available
;                                     otherwise wait in queue
           DELAY: TRIA(32.87, 39.12, 51.64); engine accessory
                                     installation
           RELEASE: WC41U: NEXT(TestC1); release the eng
                                     disassy_assy chnl
TestC1     QUEUE, TestCellQ; queue awaiting test cell
           SEIZE: WC450; seize the test cell if available
;                                     otherwise wait in the queue
           DELAY: TRIA(2.27, 3.02, 4.53); test cell operation
           RELEASE: WC450: NEXT(EngRpr); release the test cell
EngRpr     TALLY: Eng TAT, INT(TimeIn);
           COUNT: Engines repaired;
           RELEASE: EngSpare: DISPOSE; update the spare engine pool
BcmEng     COUNT: BcmEngines;
           DELAY: TRIA(165.6, 220.8, 331.2); delay awaiting return of
                                     Bcm engine
           RELEASE: Engspare: DISPOSE; update the spare engine pool

Fan        BRANCH, 1:
           WITH, .4485, FanRpr:
           WITH, .5515, FanSp; 55.15% of time fans don't require
                                     repair
FanSp      DELAY: TRIA(.75, 1, 1.5); admin delay
           RELEASE: FanSpare: DISPOSE; update the fan spare pool
FanRpr     BRANCH, 1:
           WITH, .0467, BcmFan:
           WITH, .9533, FanRpr1;

```

```

FanRpr1    QUEUE,FanAwpQ;
           ASSIGN:TimeIn1=TNOW;
           SEIZE:Awp;
           DELAY:TRIA(504.75,673,1009.5);awaiting parts
           TALLY:Fan AWP time,INT(TimeIn1);
           RELEASE:Awp;
           QUEUE,FanRepairQ1; queue awaiting fan repair
           SEIZE:WC414; seize module repair if available
           ASSIGN:TimeIn7=TNOW;
           DELAY:TRIA(6.33,22.18,53.88);fan WIP time
           TALLY:Fan WIP time,INT(TimeIn7);
           RELEASE:WC414:NEXT(Spnbalfan);release the module repair
                                           channel
FanRpr2    TALLY:Fan TAT,INT(TimeIn);
           COUNT:Fans repaired;
           RELEASE:FanSpare:DISPOSE;update the fan spare pool
BcmFan     COUNT:BcmFans;
           DELAY:TRIA(223.2,297.6,446.4);delay for ACWT
           RELEASE:FanSpare:DISPOSE; update the fan spare pool
Spnbalfan  BRANCH,1:
           WITH,.0865,Spnbalf:
           WITH,.9135,FanRpr2;91.35% of time fan does not
                                           require balancing
Spnbalf    QUEUE,Spnbalfan1Q; queue awaiting fan balance
           SEIZE:WC415;seize the spnbal repair chnl
           DELAY:TRIA(.75,2.0,8.0);delay for spnbal
           COUNT:Fansbal;
           RELEASE:WC415:NEXT(FanRpr2); release the spnbal repair
                                           chnl
Hpt        BRANCH,1:
           WITH,.5914,HptRpr:
           WITH,.4086,HptSp;    40.86% of Hpts don't require
                                           repair
HptSp     DELAY:TRIA(.75,1,1.5); admin delay
           RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
HptRpr    BRANCH,1:
           WITH,.0478,BcmHpt:
           WITH,.9522,HptRpr1;
HptRpr1   QUEUE,HptAwpQ;
           ASSIGN:TimeIn2=TNOW;
           SEIZE:Awp;
           DELAY:TRIA(428.25,571,856.5);awaiting parts
           TALLY:Hpt AWP time,INT(TimeIn2);
           RELEASE:Awp;
           QUEUE,HptRepairQ1;queue awaiting Hpt repair
           SEIZE:WC414;seize module repair if available
           ASSIGN:TimeIn8=TNOW;
           DELAY:TRIA(13.16,18.38,28.82);Hpt WIP time
           TALLY:Hpt WIP time,INT(TimeIn8);

```

```

                                RELEASE:WC414:NEXT(SpnbalHpt);release the module repair
                                channel
HptRpr2    TALLY:Hpt TAT,INT(TimeIn);
            COUNT:Hpts repaired;
            RELEASE:HptSpare:DISPOSE;update the Hpt spare pool
BcmHpt     COUNT:BcmHpts;
            DELAY:TRIA(237.6,316.8,475.2);delay for ACWT
            RELEASE:HptSpare:DISPOSE; update the Hpt spare pool
SpnbalHpt  BRANCH,1:
            WITH,.0478,SpnbalH:
            WITH,.9522,HptRpr2; 95.22% of time Hpt does not
                                require balancing
SpnbalH    QUEUE,SpnbalHpt1Q; queue awaiting Hpt spnbal
            SEIZE:WC415; seize the Spnbal repair chnl
            DELAY:TRIA(.75,2.0,8.0); delay for spnbal
            COUNT:Hptsbal;
            RELEASE:WC415:NEXT(HptRpr2); release the Spnbal repair
                                chnl
Lpt        BRANCH,1:
            WITH,.5216,LptRpr:
            WITH,.4784,LptSp;    47.84% of Lpts don't require
                                repair
LptSp      DELAY:TRIA(.75,1,1.5); admin delay
            RELEASE:LptSpare:DISPOSE; update the Lpt spare pool
LptRpr     BRANCH,1:
            WITH,.0281,BcmLpt:
            WITH,.9719,LptRpr1;
LptRpr1    QUEUE,LptAwpQ;
            ASSIGN:TimeIn3=TNOW;
            SEIZE:Awp;
            DELAY:TRIA(321,428,642);awaiting parts
            TALLY:Lpt AWP time,INT(TimeIn3);
            RELEASE:Awp;
            QUEUE,LptRepairQ1;queue awaiting Lpt repair
            SEIZE:WC414;seize module repair if available
            ASSIGN:TimeIn9=TNOW;
            DELAY:TRIA(11.16,20.04,33.79);Lpt WIP time
            TALLY:Lpt WIP time,INT(TimeIn9);
            RELEASE:WC414:NEXT(SpnbalLpt);release the module repair
                                channel
LptRpr2    TALLY:Lpt TAT,INT(TimeIn);
            COUNT:Lpts repaired;
            RELEASE:LptSpare:DISPOSE;update the Lpt spare pool
BcmLpt     COUNT:BcmLpts;
            DELAY:TRIA(138.6,184.8,277.2);delay for ACWT
            RELEASE:LptSpare:DISPOSE;update the Lpt spare pool
SpnbalLpt  BRANCH,1:
            WITH,.0172,SpnbalL:
            WITH,.9828,LptRpr2; 98.28% of time Lpt does not
                                require balancing
SpnbalL    QUEUE,SpnbalLpt1Q;

```

```

SEIZE:WC415;seize the Spnbal repair chnl
DELAY:TRIA(.75,2.0,8.0); delay for Spnbal
COUNT:Lptsbal;
RELEASE:WC415:NEXT(LptRpr2); release the Spnbal repair
                                chnl

Hpc      BRANCH,1:
          WITH,.3854,HpcRpr:
          WITH,.6146,HpcSp; 61.46% of Hpcs don't require repair
HpcSp    DELAY:TRIA(.75,1,1.5); admin delay
          RELEASE:HpcSpare:DISPOSE; update the Hpc spare pool
HpcRpr   BRANCH,1:
          WITH,.0259,BcmHpc:
          WITH,.9741,HpcRpr1;
HpcRpr1  QUEUE,HpcAwpQ;
          ASSIGN:TimeIn4=TNOW;
          SEIZE:Awp;
          DELAY:TRIA(474,632,948);awaiting parts
          TALLY:Hpc AWP time,INT(TimeIn4);
          RELEASE:Awp;
          QUEUE,HpcRepairQ1;queue awaiting Hpc repair
          SEIZE:WC414;seize module repair if available
          ASSIGN:TimeIn10=TNOW;
          DELAY:TRIA(1.00,43.87,184.57);Hpc WIP time
          TALLY:Hpc WIP time,INT(TimeIn10);
          RELEASE:WC414:NEXT(SpnbalHpc);release the module repair
                                channel
HpcRpr2  TALLY:Hpc TAT,INT(TimeIn);
          COUNT:Hpcs repaired;
          RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool
BcmHpc   COUNT:BcmHpcs;
          DELAY:TRIA(135,180,270);delay for ACWT
          RELEASE:HpcSpare:DISPOSE;update the Hpc spare pool
SpnbalHpc BRANCH,1:
          WITH,.0603,SpnbalHp:
          WITH,.9397,HpcRpr2; 93.97% of time Hpc does not
                                require balancing
SpnbalHp  QUEUE,SpnbalHpc1Q;
          SEIZE:WC415;seize the Spnbal repair chnl
          DELAY:TRIA(.75,4.0,12.0); delay for Spnbal
          COUNT:Hpcsbal;
          RELEASE:WC415:NEXT(HpcRpr2); release the Spnbal repair
                                chnl

Cmb      BRANCH,1:
          WITH,.2857,CmbRpr:
          WITH,.7143,CmbSp; 71.43% of Cmb's don't require
                                repair
CmbSp    DELAY:TRIA(.75,1,1.5); admin delay
          RELEASE:CmbSpare:DISPOSE; update the Cmb spare pool
CmbRpr   BRANCH,1:

```



```

                WITH, .0814, BcmCmb:
                WITH, .9186, CmbRpr1;
CmbRpr1  QUEUE, CmbAwpQ;
        ASSIGN:TimeIn5=TNOW;
        SEIZE:Awp;
        DELAY:TRIA(1056,1408,2112);awaiting parts
        TALLY:Cmb AWP time,INT(TimeIn5);
        RELEASE:Awp;
        QUEUE,CmbRepairQ1; queue awaiting Cmb repair
        SEIZE:WC414; seize module repair if available
        ASSIGN:TimeIn11=TNOW;
        DELAY:TRIA(10.92,12.14,14.58);Cmb WIP time
        TALLY:Cmb WIP time,INT(TimeIn11);
        RELEASE:WC414;release the module repair channel
        TALLY:Cmb TAT,INT(TimeIn);
        COUNT:Cmbs repaired;
        RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool
BcmCmb  COUNT:BcmCmbs;
        DELAY:TRIA(208.8,278.4,417.6);delay for ACWT
        RELEASE:CmbSpare:DISPOSE;update the Cmb spare pool

Afb  BRANCH,1:
        WITH, .6179, AfbRpr:
        WITH, .3821, AfbSp; 38.21% of Afbs don't require repair
AfbSp  DELAY:TRIA(.75,1,1.5); admin delay
        RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
AfbRpr  BRANCH,1:
        WITH, .0038, BcmAfb:
        WITH, .9962, AfbRpr1;
AfbRpr1  QUEUE, AfbAwpQ;
        ASSIGN:TimeIn6=TNOW;
        SEIZE:Awp;
        DELAY:TRIA(244.5,326,489);awaiting parts
        TALLY:Afb AWP time,INT(TimeIn6);
        RELEASE:Awp;
        QUEUE,AfbRepairQ1; queue awaiting Afb repair
        SEIZE:WC413; seize the module repair channel
        ASSIGN:TimeIn12=TNOW;
        DELAY:TRIA(9.95,11.80,15.50);Afb WIP time
        TALLY:Afb WIP time,INT(TimeIn12);
        RELEASE:WC413;release the module repair channel
        TALLY:Afb TAT,INT(TimeIn);
        COUNT:Afbs repaired;
        RELEASE:AfbSpare:DISPOSE;update the Afb spare pool
BcmAfb  COUNT:BcmAfbs;
        DELAY:TRIA(178.2,237.6,356.4);delay for ACWT
        RELEASE:AfbSpare:DISPOSE;update the Afb spare pool

END;

```

Experiment File-Expanded AIMD Cecil Field with Triangular
Distribution

```
BEGIN;
PROJECT, Proposed AIMD C.Field Model, P.Braun and S.Bartlett;
ATTRIBUTES:TimeIn:TimeIn1:TimeIn2:TimeIn3:TimeIn4:TimeIn5:
            TimeIn6:TimeIn7:TimeIn8:TimeIn9:TimeIn10:TimeIn11:
            TimeIn12;
QUEUES:EngSpareQ:MainChnl1Q:MainChnl2Q:TestCellQ:
        FanAssyQ:FanAssy1Q:HptAssyQ:HptAssy1Q:
        LptAssyQ:LptAssy1Q:HpcAssyQ:HpcAssy1Q:CmbAssyQ:
        CmbAssy1Q:AfbAssyQ:AfbAssy1Q:FanRepairQ1:FanAwpQ:
        HptRepairQ1:HptAwpQ:LptRepairQ1:LptAwpQ:HpcRepairQ1:
        HpcAwpQ:CmbRepairQ1:CmbAwpQ:AfbRepairQ1:AfbAwpQ:
        SpnbalFan1Q:SpnbalHpt1Q:SpnbalLpt1Q:SpnbalHpc1Q;
RESOURCES: WC41U,4: ! # of main engine disass_assy channels
            WC450,2: ! # of test cell channels
            WC414,3: ! # of module repair channels
            WC413,1: ! # of Afb repair channels
            WC415,1: ! # of Spnbal repair channels
            EngSpare,12: ! # of spare engines
            FanSpare,12: ! # of spare fans
            HptSpare,12: ! # of spare Hpts
            LptSpare,12: ! # of spare Lpts
            HpcSpare,12: ! # of spare Hpcs
            CmbSpare,10: ! # of spare Cmbs
            AfbSpare,7: ! # of spare Afbs
            Awp,1000; # of Awp channels
TALLIES:  Time AC AWP:
            AC TAT:
            Eng AWP:
            Eng TAT:
            Fan TAT:
            Hpc TAT:
            Hpt TAT:
            Lpt TAT:
            Cmb TAT:
            Afb TAT:
            Fan AWP time:
            Hpc AWP time:
            Hpt AWP time:
            Lpt AWP time:
            Cmb AWP time:
            Afb AWP time:
            Fan WIP time:
            Hpc WIP time:
            Hpt WIP time:
            Lpt WIP time:
            Cmb WIP time:
            Afb WIP time;
DSTAT:    (NR(WC41U)/4)*100, Eng disass_assy chnl use:
            (NR(WC450)/2)*100, Test cell chnl use:
```

```

(NR(WC414)/3)*100, Module repair chnl use:
(NR(WC413)/1)*100, Afb repair chnl use:
(NR(WC415)/1)*100, Spnbal repair chnl use:
NQ(EngSpareQ), Num AC awtg eng:
NR(EngSpare), Avg EngSpare use:
NR(FanSpare), Avg FanSpare use:
NR(HpcSpare), Avg HpcSpare use:
NR(HptSpare), Avg HptSpare use:
NR(LptSpare), Avg LptSpare use:
NR(CmbSpare), Avg CmbSpare use:
NR(AfbSpare), Avg AfbSpare use;
COUNTERS: AC engines processed:Engines repaired:Fans repaired:
Hpts repaired:Lpts repaired:Hpcs repaired:Cmbs
repaired:Afbs repaired:BcmEngines:BcmFans:BcmHpts:
BcmLpts:BcmHpcs:
BcmCmbs:BcmAfbs:Fansbal:Hptsbal:Lptsbal:Hpcsbal;
SEEDS:1,434780; Seed for random number generation
REPLICATE, 10,0,8760,No,Yes,43800;
END;

```

APPENDIX D

CURRENT AIMD CECIL FIELD OUTPUT, LOG NORMAL DISTRIBUTION

SIMAN IV - License #9010699
Naval Post-Graduate School

Summary for Replication 1 of 10

Project: Existing AIMD C.Field Model Run execution date:5/17/1993
Analyst: P.Braun and S.Bartlett Model revision date:5/17/1993

Replication ended at time : 52560.0
Statistics were cleared at time: 43800.0
Statistics accumulated for time: 8760.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
Time AC AWP	10.167	1.6741	2.3008	94.473	324
AC TAT	15.709	1.0814	5.6250	98.980	324
Eng AWP	183.49	.45792	23.000	380.03	309
Eng TAT	227.55	.36733	56.148	427.13	311
Fan TAT	808.29	.17327	553.23	1310.6	127
Hpc TAT	829.82	.20215	529.63	1618.9	115
Hpt TAT	707.75	.17699	476.43	1090.1	160
Lpt TAT	539.68	.19715	305.95	829.84	148
Cmb TAT	1660.5	.18177	1108.3	2393.9	72
Afb TAT	417.41	.17320	256.24	622.95	192
Fan AWP time	761.42	.18218	521.41	1247.6	126
Hpc AWP time	751.12	.20897	441.23	1184.1	113
Hpt AWP time	662.23	.18938	432.82	1049.1	160
Lpt AWP time	490.97	.21536	269.25	766.30	145
Cmb AWP time	1620.4	.18490	1081.4	2358.1	72
Afb AWP time	380.61	.18890	224.32	582.98	194
Fan WIP time	20.662	.75520	3.2852	141.58	127
Hpc WIP time	48.560	2.1905	1.5156	1015.2	115
Hpt WIP time	17.507	.25859	9.2891	34.180	160
Lpt WIP time	17.099	.56262	3.5859	57.770	148
Cmb WIP time	9.6128	.13360	6.9023	12.563	72
Afb WIP time	9.6555	.19864	5.8359	16.449	192

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
Eng disass_assy chnl u	53.714	.59971	.00000	100.00	25.000
Test cell chnl use	5.3584	3.0847	.00000	100.00	.00000
Module repair chnl use	53.533	.65814	.00000	100.00	.00000
Afb repair chnl use	21.210	1.9274	.00000	100.00	100.00
Num AC awtg eng	.23508	3.3119	.00000	6.0000	.00000
Avg EngSpare use	8.1223	.33347	1.0000	12.000	9.0000
Avg FanSpare use	10.783	.12288	7.0000	12.000	12.000
Avg HpcSpare use	10.251	.18096	5.0000	12.000	12.000
Avg HptSpare use	11.465	.09480	7.0000	12.000	12.000
Avg LptSpare use	8.7467	.24926	3.0000	12.000	12.000
Avg CmbSpare use	9.8002	.06474	6.0000	10.000	10.000
Avg AfbSpare use	6.6479	.10955	3.0000	7.0000	7.0000

COUNTERS

Identifier	Count	Limit
AC engines processed	324	Infinite
Engines repaired	311	Infinite
Fans repaired	127	Infinite
Hpts repaired	160	Infinite
Lpts repaired	148	Infinite
Hpcs repaired	115	Infinite
Cmbs repaired	72	Infinite
Afbs repaired	192	Infinite
BcmEngines	12	Infinite
BcmFans	16	Infinite
BcmHpts	15	Infinite
BcmLpts	8	Infinite
BcmHpcs	10	Infinite
BcmCmbs	11	Infinite
BcmAfbs	1	Infinite

CURRENT AIMD CECIL FIELD OUTPUT, TRIANGULAR DISTRIBUTION

SIMAN IV - License #9010699
Naval Post-Graduate School

Summary for Replication 1 of 10

Project:Existing AIMD C.Field Model
Analyst:P.Braun and S.Bartlett

Run execution date:5/17/1993
Model revision date:5/17/1993

Replication ended at time : 52560.0
Statistics were cleared at time: 43800.0
Statistics accumulated for time: 8760.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
Time AC AWP	14.818	1.5668	2.9414	137.23	324
AC TAT	21.037	1.1053	7.7969	145.06	324
Eng AWP	210.07	.43907	34.215	453.50	309
Eng TAT	256.60	.35399	85.758	501.87	310
Fan TAT	914.29	.12584	692.08	1210.7	127
Hpc TAT	929.11	.14190	644.29	1285.0	106
Hpt TAT	774.45	.13490	572.74	1040.3	164
Lpt TAT	609.00	.13334	446.05	787.05	152
Cmb TAT	1833.7	.14425	1355.5	2412.3	73
Afb TAT	452.91	.13225	340.76	613.88	197
Fan AWP time	854.78	.13467	642.02	1139.8	127
Hpc AWP time	797.63	.15302	568.60	1037.4	107
Hpt AWP time	720.01	.14497	529.61	997.35	164
Lpt AWP time	551.71	.14675	402.58	725.49	152
Cmb AWP time	1749.1	.14318	1308.6	2318.5	73
Afb AWP time	413.40	.14308	305.28	571.26	197
Fan WIP time	26.300	.37317	10.016	51.813	127
Hpc WIP time	80.676	.48785	5.0898	177.95	106
Hpt WIP time	20.163	.16482	13.527	28.137	164
Lpt WIP time	19.243	.29844	8.4883	31.266	152
Cmb WIP time	10.148	.08297	8.6484	11.969	73
Afb WIP time	10.069	.12153	7.8516	12.629	197

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
Eng disass_assy chnl u	55.675	.58252	.00000	100.00	25.000
Test cell chnl use	5.7946	2.9220	.00000	100.00	.00000
Module repair chnl use	71.886	.46731	.00000	100.00	33.333
Afb repair chnl use	22.645	1.8483	.00000	100.00	.00000
Num AC awtg eng	.39548	2.4458	.00000	6.0000	.00000
Avg EngSpare use	9.0048	.29796	2.0000	12.000	5.0000
Avg FanSpare use	11.581	.08287	6.0000	12.000	12.000
Avg HpcSpare use	10.216	.16462	6.0000	12.000	10.000
Avg HptSpare use	11.720	.06038	8.0000	12.000	12.000
Avg LptSpare use	10.106	.17018	5.0000	12.000	12.000
Avg CmbSpare use	9.9848	.01228	9.0000	10.000	10.000
Avg AfbSpare use	6.8319	.07926	4.0000	7.0000	7.0000

COUNTERS

Identifier	Count	Limit
AC engines processed	324	Infinite
Engines repaired	310	Infinite
Fans repaired	127	Infinite
Hpts repaired	164	Infinite
Lpts repaired	152	Infinite
Hpcs repaired	106	Infinite
Cmbs repaired	73	Infinite
Afbs repaired	197	Infinite
BcmEngines	15	Infinite
BcmFans	14	Infinite
BcmHpts	24	Infinite
BcmLpts	6	Infinite
BcmHpcs	15	Infinite
BcmCmbs	12	Infinite
BcmAfbs	2	Infinite

EXPANDED AIMD CECIL FIELD OUTPUT, LOG NORMAL DISTRIBUTION

SIMAN IV - License #9010699
Naval Post-Graduate School

Summary for Replication 1 of 10

Project: Proposed AIMD C.Field Model Run execution date:5/17/1993
Analyst: P.Braun and S.Bartlett Model revision date:5/17/1993

Replication ended at time : 52560.0
Statistics were cleared at time: 43800.0
Statistics accumulated for time: 8760.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
Time AC AWP	5.0886	1.5712	2.1328	82.133	324
AC TAT	10.870	.73455	6.0000	87.129	325
Eng AWP	149.46	.52264	15.934	358.06	320
Eng TAT	193.64	.40334	55.559	398.85	320
Fan TAT	710.36	.19166	445.14	1073.2	127
Hpc TAT	692.86	.20732	429.93	1176.7	104
Hpt TAT	612.71	.18310	381.38	890.08	175
Lpt TAT	482.62	.19004	288.39	866.31	159
Cmb TAT	1467.2	.14823	1060.6	2018.0	81
Afb TAT	371.42	.17316	241.20	584.19	188
Fan AWP time	658.09	.20329	397.87	1023.3	127
Hpc AWP time	615.88	.19851	384.24	1021.9	104
Hpt AWP time	563.59	.19742	342.88	846.65	172
Lpt AWP time	434.83	.20698	255.55	814.59	161
Cmb AWP time	1426.5	.15190	1019.3	1982.8	81
Afb AWP time	331.89	.19206	205.31	541.08	188
Fan WIP time	23.424	.76888	3.5430	148.69	127
Hpc WIP time	45.363	1.1656	.51953	304.67	104
Hpt WIP time	18.775	.30302	8.4609	36.430	175
Lpt WIP time	18.291	.49161	5.2461	62.027	159
Cmb WIP time	12.178	.13810	8.9922	16.332	81
Afb WIP time	11.696	.19715	7.5039	19.059	188

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
Eng disass_assy chnl u	54.379	.57713	.00000	100.00	50.000
Test cell chnl use	5.4381	2.9950	.00000	100.00	.00000
Module repair chnl use	56.562	.61543	.00000	100.00	66.667
Afb repair chnl use	25.025	1.7309	.00000	100.00	100.00
Spnbal repair chnl use	.74981	11.505	.00000	100.00	.00000
Num AC awtg eng	.04841	6.1080	.00000	3.0000	.00000
Avg EngSpare use	7.0813	.40005	.00000	12.000	5.0000
Avg FanSpare use	10.244	.15746	5.0000	12.000	10.000
Avg HpcSpare use	8.0800	.24511	4.0000	12.000	7.0000
Avg HptSpare use	10.579	.17339	5.0000	12.000	12.000
Avg LptSpare use	8.4682	.28563	2.0000	12.000	9.0000
Avg CmbSpare use	9.3258	.17653	3.0000	10.000	10.000
Avg AfbSpare use	6.2527	.23300	1.0000	7.0000	7.0000

COUNTERS

Identifier	Count	Limit
AC engines processed	325	Infinite
Engines repaired	320	Infinite
Fans repaired	127	Infinite
Hpts repaired	175	Infinite
Lpts repaired	159	Infinite
Hpcs repaired	104	Infinite
Cmbs repaired	81	Infinite
Afbs repaired	188	Infinite
BcmEngines	10	Infinite
BcmFans	14	Infinite
BcmHpts	10	Infinite
BcmLpts	7	Infinite
BcmHpcs	3	Infinite
BcmCmbs	13	Infinite
BcmAfbs	1	Infinite
Fansbal	9	Infinite
Hptsbal	8	Infinite
Lptsbal	2	Infinite
Hpcsbal	7	Infinite

EXPANDED AIMD CECIL FIELD OUTPUT, TRIANGULAR DISTRIBUTION

SIMAN IV - License #9010699
 Naval Post-Graduate School

Summary for Replication 1 of 10

Project: Proposed AIMD C.Field Model Run execution date:5/17/1993
 Analyst: P.Braun and S.Bartlett Model revision date:5/17/1993

Replication ended at time : 52560.0
 Statistics were cleared at time: 43800.0
 Statistics accumulated for time: 8760.0

TALLY VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Observations
Time AC AWP	14.569	1.7598	2.9023	176.47	323
AC TAT	20.673	1.2411	8.0938	181.77	324
Eng AWP	226.18	.37638	41.258	483.59	304
Eng TAT	271.02	.30881	69.141	523.54	304
Fan TAT	797.26	.13785	585.59	1026.1	138
Hpc TAT	816.99	.13694	572.12	1122.8	112
Hpt TAT	671.41	.12987	494.74	906.04	172
Lpt TAT	523.01	.13271	392.09	746.08	153
Cmb TAT	1651.6	.16523	1182.9	2435.9	81
Afb TAT	392.64	.11908	292.04	506.31	179
Fan AWP time	732.83	.15003	537.76	978.52	140
Hpc AWP time	674.36	.14029	484.21	885.04	109
Hpt AWP time	615.04	.13594	438.34	834.56	174
Lpt AWP time	455.45	.14077	342.65	636.72	154
Cmb AWP time	1529.3	.15462	1145.2	2046.5	82
Afb AWP time	350.45	.13184	253.92	460.54	179
Fan WIP time	28.153	.35246	9.0547	52.105	138
Hpc WIP time	78.069	.55805	8.4453	177.75	112
Hpt WIP time	19.796	.14900	14.441	27.254	172
Lpt WIP time	21.490	.22434	12.727	32.531	153
Cmb WIP time	12.629	.05700	11.246	14.277	81
Afb WIP time	12.409	.09467	10.289	14.844	179

DISCRETE-CHANGE VARIABLES

Identifier	Average	Variation	Minimum	Maximum	Final Value
Eng disass_assy chnl u	55.195	.57870	.00000	100.00	50.000
Test cell chnl use	5.6735	2.9746	.00000	100.00	.00000
Module repair chnl use	77.106	.41316	.00000	100.00	100.00
Afb repair chnl use	25.355	1.7158	.00000	100.00	.00000
Spnbal repair chnl use	1.3254	8.6284	.00000	100.00	.00000
Num AC awtg eng	.38757	2.6902	.00000	7.0000	1.0000
Avg EngSpare use	9.5329	.23332	2.0000	12.000	12.000
Avg FanSpare use	11.315	.09982	7.0000	12.000	12.000
Avg HpcSpare use	9.8743	.20127	5.0000	12.000	9.0000
Avg HptSpare use	11.306	.10891	7.0000	12.000	12.000
Avg LptSpare use	8.8328	.28798	2.0000	12.000	8.0000
Avg CmbSpare use	9.9939	.00789	9.0000	10.000	10.000
Avg AfbSpare use	6.4750	.14740	3.0000	7.0000	6.0000

COUNTERS

Identifier	Count	Limit
AC engines processed	324	Infinite
Engines repaired	304	Infinite
Fans repaired	138	Infinite
Hpts repaired	172	Infinite
Lpts repaired	153	Infinite
Hpcs repaired	112	Infinite
Cmbs repaired	81	Infinite
Afbs repaired	179	Infinite
BcmEngines	13	Infinite
BcmFans	9	Infinite
BcmHpts	11	Infinite
BcmLpts	6	Infinite
BcmHpcs	2	Infinite
BcmCmbs	8	Infinite
BcmAfbs	1	Infinite
Fansbal	6	Infinite
Hptsbal	8	Infinite
Lptsbal	3	Infinite
Hpcsbal	9	Infinite

APPENDIX E

SUMMARY OF RESULTS FOR CURRENT AIMD CECIL FIELD WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	10.17	15.04	18.42	12.06	6.50	30.90	20.01	19.13	11.24	42.97	18.95	10.93	3.46
AC TAT (HRS)	15.71	20.76	24.25	17.74	12.27	36.63	25.72	24.85	16.90	48.89	24.36	10.94	3.46
Eng AWP (HRS)	183.49	208.91	217.52	172.71	197.66	236.47	212.39	244.52	218.72	218.81	210.29	21.72	6.87
Eng TAT (HRS)	227.55	250.82	260.18	215.06	240.16	281.04	257.90	268.90	257.03	260.68	263.90	21.86	6.91
Fen TAT (HRS)	808.29	850.05	825.67	847.46	828.27	852.91	808.65	822.08	852.27	820.85	851.16	19.38	5.81
Hpc TAT (HRS)	820.82	857.79	897.61	802.90	870.27	787.39	848.09	795.21	814.02	788.98	821.20	27.88	8.82
Hpr TAT (HRS)	707.75	728.40	730.78	722.94	710.31	722.18	709.85	717.11	718.00	727.30	718.76	8.25	2.61
Lpt TAT (HRS)	590.68	594.99	650.38	641.72	599.04	650.33	647.41	634.98	646.34	653.18	644.38	7.68	2.39
Onb TAT (HRS)	1690.50	1693.70	1679.80	1790.40	1720.30	1621.40	1814.50	1746.90	1674.50	1647.30	1695.47	57.85	18.29
Ab TAT (HRS)	417.41	421.81	417.94	416.57	422.47	426.97	430.99	417.20	414.99	414.18	416.74	6.12	1.82
Fen AWP (HRS)	781.42	798.57	778.12	799.29	775.31	806.81	763.77	774.44	801.99	771.88	782.14	18.39	5.81
Hpc AWP (HRS)	761.12	767.84	770.34	759.26	761.27	719.95	769.90	729.90	783.66	720.44	744.31	18.57	5.87
Hpr AWP (HRS)	682.23	680.21	684.08	676.96	683.58	677.13	682.46	672.24	685.25	682.39	672.95	8.68	2.78
Lpt AWP (HRS)	490.97	489.69	500.95	497.11	491.78	510.82	503.85	491.96	502.06	509.80	499.46	8.23	2.80
Onb AWP (HRS)	1620.40	1617.50	1640.10	1622.00	1629.40	1590.50	1777.40	1710.20	1689.80	1608.00	1650.79	58.90	18.68
Ab AWP (HRS)	390.61	385.58	381.45	390.65	385.76	386.18	394.35	390.85	379.36	377.24	383.21	4.92	1.55
Fen WIP (HRS)	20.66	21.98	20.84	20.82	23.81	19.70	22.00	22.37	22.69	21.70	21.82	1.22	0.39
Hpc WIP (HRS)	49.56	37.02	36.94	36.24	57.16	36.70	54.60	36.76	51.29	39.28	44.04	7.98	2.51
Hpr WIP (HRS)	17.51	17.95	18.25	18.45	18.14	19.00	17.90	18.95	18.73	18.48	18.29	0.48	0.14
Lpt WIP (HRS)	17.10	15.30	15.12	18.43	16.81	16.15	15.82	16.20	16.72	15.16	16.06	0.89	0.22
Onb WIP (HRS)	9.61	9.86	9.54	9.74	9.91	9.75	9.78	9.72	9.80	9.82	9.78	0.11	0.04
Ab WIP (HRS)	9.66	9.46	9.30	9.09	9.53	9.49	9.40	9.52	9.51	9.46	9.45	0.16	0.06
WC 41U Utilization %	63.71	60.10	47.82	49.13	46.35	61.20	49.57	47.44	50.11	61.88	49.78	2.20	0.70
WC 460 Utilization %	5.96	5.06	4.85	4.81	4.88	5.15	4.94	4.81	5.08	5.13	4.98	0.21	0.07
WC 414 Utilization %	63.53	47.39	44.61	46.09	54.41	48.70	48.17	47.87	53.81	50.06	49.44	3.42	1.06
WC 413 Utilization %	21.21	18.25	18.67	17.53	18.93	21.88	19.00	19.13	20.95	18.96	19.24	1.85	0.62
Num AC AWP (UNITS)	0.24	0.39	0.46	0.29	0.09	0.99	0.66	0.50	0.26	1.44	0.82	0.40	0.13
AC Eng processed (UNITS)	824.00	905.00	289.00	904.00	281.00	902.00	902.00	289.00	909.00	923.00	902.70	14.10	4.46
Engines repaired (UNITS)	311.00	295.00	282.00	282.00	271.00	289.00	289.00	289.00	284.00	290.00	290.00	11.72	3.71
Fens repaired (UNITS)	127.00	128.00	114.00	105.00	98.00	113.00	107.00	108.00	105.00	120.00	111.90	10.08	3.17
Hpts repaired (UNITS)	180.00	160.00	189.00	159.00	145.00	189.00	140.00	185.00	169.00	144.00	164.90	9.92	3.14
Lpts repaired (UNITS)	148.00	145.00	137.00	147.00	131.00	147.00	136.00	155.00	154.00	147.00	144.90	7.99	2.50
Hpcs repaired (UNITS)	115.00	107.00	99.00	109.00	113.00	109.00	90.00	102.00	102.00	123.00	109.90	9.27	2.98
Onbs repaired (UNITS)	72.00	80.00	81.00	65.00	78.00	81.00	77.00	85.00	81.00	85.00	78.50	6.08	1.92
Abbs repaired (UNITS)	192.00	199.00	167.00	199.00	174.00	202.00	177.00	178.00	183.00	178.00	178.20	19.52	4.28
BomEngines (UNITS)	12.00	13.00	12.00	13.00	13.00	8.00	13.00	10.00	15.00	14.00	12.90	2.00	0.68
BomFens (UNITS)	16.00	20.00	12.00	19.00	20.00	28.00	18.00	21.00	8.00	21.00	17.80	4.61	1.46
BomHpts (UNITS)	15.00	16.00	14.00	19.00	13.00	18.00	19.00	21.00	18.00	18.00	16.40	2.78	0.87
BomLpts (UNITS)	9.00	8.00	5.00	9.00	9.00	7.00	9.00	9.00	8.00	15.00	8.90	2.95	0.81
BomHpcs (UNITS)	10.00	8.00	5.00	7.00	7.00	11.00	10.00	5.00	12.00	11.00	8.90	2.95	0.81
BomOnbs (UNITS)	11.00	7.00	9.00	7.00	8.00	10.00	8.00	10.00	6.00	8.00	8.40	1.98	0.60
BomAbbs (UNITS)	1.00	1.00	2.00	1.00	1.00	1.00	3.00	1.00	0.00	2.00	1.90	0.82	0.26

SUMMARY OF RESULTS FOR CURRENT AND CECIL FIELD WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Aug EngSpore use (UNITS)	8.12	8.11	8.01	7.16	7.48	8.57	8.13	8.78	8.53	7.97	8.09	0.61	0.16
Aug FerSpore use (UNITS)	10.78	10.58	10.16	9.71	9.18	10.05	9.08	9.19	9.81	10.46	9.94	0.55	0.17
Aug HpcSpore use (UNITS)	10.26	9.19	9.05	9.55	9.28	9.39	8.80	8.82	8.95	10.28	9.34	0.58	0.18
Aug HysSpore use (UNITS)	11.47	10.44	10.84	11.48	10.46	11.10	10.40	10.81	11.12	10.78	10.87	0.38	0.12
Aug LysSpore use (UNITS)	8.75	8.18	8.16	8.69	7.67	8.85	8.23	8.88	8.98	9.04	8.54	0.45	0.14
Aug CmbSpore use (UNITS)	9.80	9.58	9.94	9.95	9.94	9.98	10.00	9.94	9.98	9.90	9.88	0.14	0.04
Aug AbsSpore use (UNITS)	6.85	6.19	6.17	6.28	6.11	6.81	6.46	6.32	6.45	6.28	6.35	0.18	0.06

SUMMARY OF RESULTS FOR CURRENT AND CECIL FIELD WITH TRIANGULAR DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	14.82	26.80	32.68	62.67	12.46	66.66	7.58	16.08	26.81	69.07	31.75	20.66	6.63
AC TAT (HRS)	21.04	38.04	38.78	66.76	18.70	62.69	13.82	22.28	35.07	66.31	37.68	20.62	6.52
Eng AWP (HRS)	210.07	261.23	247.02	301.08	194.06	262.65	182.12	251.46	266.65	268.21	246.64	36.63	12.63
Eng TAT (HRS)	266.60	307.96	264.30	360.71	241.47	339.82	227.51	300.06	310.40	311.50	294.01	40.99	12.77
Fen TAT (HRS)	914.29	904.65	981.21	989.76	910.02	928.36	925.13	918.46	909.15	908.08	913.91	12.46	3.94
Hpc TAT (HRS)	928.11	928.08	913.46	988.14	931.06	998.98	980.35	979.95	921.91	928.55	935.73	19.70	6.23
Hpt TAT (HRS)	774.46	798.79	768.49	768.41	768.41	774.39	765.50	768.42	777.87	778.36	768.76	7.94	2.51
Lpt TAT (HRS)	609.00	619.22	608.52	609.41	608.94	604.35	603.12	605.47	611.59	606.79	605.63	6.13	1.94
Cmb TAT (HRS)	1683.70	1661.10	1902.90	1913.90	1863.20	1940.70	1902.30	1907.00	1865.40	1854.90	1864.50	33.34	10.54
Ab TAT (HRS)	462.91	469.36	461.40	462.44	448.94	460.35	460.24	463.90	469.57	465.54	466.86	4.76	1.50
Fen AWP (HRS)	854.76	848.12	872.00	890.05	853.26	864.00	866.36	858.50	848.64	852.42	854.32	12.29	3.89
Hpc AWP (HRS)	797.68	807.91	805.61	813.35	807.37	809.81	818.74	820.58	799.30	790.46	808.02	10.74	3.40
Hpt AWP (HRS)	720.01	739.39	740.52	726.09	730.22	717.86	741.00	724.56	719.23	721.78	728.05	9.16	2.90
Lpt AWP (HRS)	551.71	551.46	540.46	550.67	545.46	539.90	545.95	548.95	548.90	545.92	545.90	5.50	1.74
Cmb AWP (HRS)	1749.10	1799.90	1681.90	1622.70	1773.40	1808.10	1848.90	1794.10	1769.90	1790.00	1797.77	23.94	9.47
Ab AWP (HRS)	413.40	421.94	423.01	412.79	410.27	421.52	422.24	415.36	421.07	416.98	417.95	4.68	1.46
Fen WIP (HRS)	26.30	27.47	27.10	27.14	26.01	26.85	25.68	26.59	26.98	26.67	26.76	0.96	0.30
Hpc WIP (HRS)	80.66	74.23	66.42	74.51	78.86	84.25	76.90	77.84	80.85	78.92	78.44	4.93	1.56
Hpt WIP (HRS)	20.16	20.25	19.94	19.90	20.37	20.19	20.15	20.37	20.06	20.06	20.14	0.16	0.05
Lpt WIP (HRS)	19.24	19.56	19.85	18.86	18.65	18.76	19.05	19.20	19.91	19.13	19.11	0.47	0.15
Cmb WIP (HRS)	10.16	10.07	10.20	10.20	10.05	10.07	10.01	10.16	10.13	10.11	10.12	0.07	0.02
Ab WIP (HRS)	10.07	10.06	10.19	10.02	9.98	10.01	9.97	10.15	10.15	10.08	10.07	0.06	0.03
WC 411U Utilization %	55.68	52.15	52.05	52.26	49.52	52.50	51.96	49.69	53.16	58.30	52.54	2.12	0.87
WC 460 Utilization %	5.78	5.33	5.35	5.25	5.23	5.37	5.35	5.16	5.46	5.79	5.40	0.21	0.06
WC 414 Utilization %	71.99	65.36	66.76	66.95	61.45	66.19	60.79	70.69	71.02	69.29	67.20	3.65	1.22
WC 418 Utilization %	22.65	20.99	20.14	20.25	17.28	21.09	18.55	20.17	19.94	20.54	20.11	1.42	0.45
Num AC AWP (UNITS)	0.40	0.79	0.94	2.08	0.27	1.90	0.12	0.39	0.87	2.08	0.96	0.79	0.23
AC Eng processed (UNITS)	324.00	304.00	290.00	304.00	281.00	302.00	302.00	298.00	300.00	323.00	302.70	13.98	4.42
Engines repaired (UNITS)	310.00	284.00	290.00	285.00	278.00	290.00	284.00	277.00	292.00	311.00	299.90	11.92	3.77
Fans repaired (UNITS)	127.00	116.00	108.00	113.00	124.00	101.00	105.00	110.00	116.00	110.00	112.80	8.23	2.90
Hpts repaired (UNITS)	164.00	150.00	149.00	162.00	140.00	161.00	143.00	165.00	153.00	169.00	155.90	9.98	3.16
Hpos repaired (UNITS)	162.00	146.00	148.00	134.00	135.00	149.00	125.00	147.00	152.00	140.00	142.10	8.67	2.74
Hpos repaired (UNITS)	106.00	101.00	120.00	112.00	92.00	94.00	96.00	118.00	107.00	110.00	105.10	8.16	2.90
Cmb repaired (UNITS)	73.00	74.00	80.00	74.00	78.00	77.00	86.00	77.00	79.00	89.00	76.90	5.43	1.72
Ab repaired (UNITS)	197.00	178.00	174.00	177.00	162.00	184.00	168.00	174.00	172.00	178.00	174.90	11.88	3.76
BomEngines (UNITS)	15.00	14.00	10.00	10.00	12.00	10.00	13.00	17.00	13.00	11.00	12.60	2.97	0.76
BomFans (UNITS)	14.00	15.00	27.00	17.00	21.00	17.00	18.00	19.00	16.00	20.00	18.40	3.72	1.18
BomHpts (UNITS)	24.00	19.00	13.00	15.00	15.00	16.00	19.00	16.00	18.00	22.00	17.70	3.40	1.06
BomHpos (UNITS)	6.00	7.00	7.00	6.00	6.00	6.00	11.00	8.00	9.00	11.00	7.90	2.64	0.84
BomHpos (UNITS)	16.00	16.00	9.00	12.00	6.00	9.00	4.00	10.00	8.00	9.00	9.80	3.71	1.17
BomCmb (UNITS)	12.00	10.00	14.00	6.00	10.00	10.00	7.00	7.00	3.00	14.00	9.50	3.41	1.06
BomAb (UNITS)	2.00	1.00	1.00	0.00	2.00	1.00	2.00	1.00	1.00	1.00	1.20	0.63	0.20

SUMMARY OF RESULTS FOR CURRENT AIMD CECIL FIELD WITH TRIANGULAR DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Avg EngSpore use (UNITS)	9.00	9.56	8.72	9.76	7.91	9.59	7.60	9.26	9.91	9.16	9.66	0.96	0.26
Avg FarSpore use (UNITS)	11.56	10.66	10.99	10.92	10.95	10.13	10.36	10.96	11.06	10.60	10.90	0.42	0.13
Avg HpdSpore use (UNITS)	10.22	10.11	11.05	10.76	9.02	9.95	10.06	10.51	10.18	9.72	10.65	0.70	0.22
Avg HpdSpore use (UNITS)	11.72	11.95	11.27	11.36	11.02	11.41	11.26	11.45	11.96	11.75	11.90	0.21	0.07
Avg LpdSpore use (UNITS)	10.11	9.41	9.19	9.82	8.46	8.94	8.49	8.97	9.82	9.36	9.20	0.52	0.17
Avg CmbSpore use (UNITS)	9.96	10.00	9.94	9.96	9.99	9.86	9.95	10.00	9.96	9.99	9.90	0.20	0.06
Avg AbsSpore use (UNITS)	6.65	6.46	6.61	6.63	6.26	6.55	6.26	6.51	6.67	6.61	6.56	0.19	0.06

SUMMARY OF RESULTS FOR CURRENT AND LEMOORE WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	3.85	3.72	3.81	3.78	3.84	4.01	3.89	3.84	3.78	4.22	3.87	0.15	0.05
AC TAT (HRS)	9.80	9.46	9.43	9.59	9.59	9.82	9.59	9.55	9.50	9.90	9.50	0.15	0.05
Eng AWP (HRS)	40.55	55.98	49.15	28.25	47.74	79.34	53.52	45.21	76.72	65.95	58.44	18.52	5.96
Eng TAT (HRS)	68.15	92.54	76.52	52.77	74.07	99.18	80.98	71.47	109.91	110.75	82.70	18.31	5.79
Fen TAT (HRS)	822.71	828.99	882.88	888.32	841.52	857.32	875.88	879.28	888.18	843.49	849.18	20.30	8.42
Hpc TAT (HRS)	768.04	740.97	787.97	788.93	782.74	775.81	804.28	781.78	787.95	789.63	777.90	18.76	5.83
Hpt TAT (HRS)	208.78	209.69	216.46	208.08	208.29	211.85	214.45	211.28	216.75	208.32	210.99	3.88	1.28
Lpt TAT (HRS)	145.99	159.89	150.91	141.32	143.17	148.75	149.02	148.76	149.48	144.70	145.40	3.95	1.25
Chb TAT (HRS)	889.01	707.57	729.30	717.20	687.87	719.48	711.94	704.22	712.79	689.85	708.17	10.83	3.42
Fen AWP (HRS)	132.14	145.99	130.35	130.83	133.50	133.53	134.16	137.18	140.08	130.71	136.34	4.55	1.44
Hpc AWP (HRS)	787.19	785.88	800.08	777.50	784.74	779.74	818.07	818.82	805.40	788.15	789.86	19.13	6.05
Hpt AWP (HRS)	717.85	688.03	732.27	734.47	705.13	723.84	748.90	723.80	739.07	735.12	724.30	17.71	5.80
Lpt AWP (HRS)	188.20	183.39	174.27	185.82	183.47	188.78	187.50	185.88	170.98	182.48	188.95	3.60	1.14
Chb AWP (HRS)	71.17	72.67	72.98	71.38	72.57	72.18	74.00	71.82	71.17	71.41	72.13	0.93	0.29
Ab AWP (HRS)	657.88	670.67	688.19	685.53	685.83	684.48	679.98	688.17	688.98	657.88	674.01	11.35	3.59
Fen WIP (HRS)	98.91	98.14	98.09	94.59	98.32	95.00	95.40	95.79	94.97	95.08	95.68	1.21	0.38
Hpc WIP (HRS)	41.70	42.22	45.78	43.82	38.90	38.32	48.45	42.78	41.72	48.43	42.17	2.24	0.71
Hpt WIP (HRS)	30.81	34.54	34.65	34.51	33.22	38.32	37.41	35.44	32.59	39.84	34.09	1.78	0.58
Lpt WIP (HRS)	23.88	25.98	24.24	23.58	28.14	27.48	28.57	28.58	28.00	25.59	25.78	1.58	0.50
Chb WIP (HRS)	68.13	81.82	48.75	53.58	52.26	59.08	52.90	53.78	54.90	55.03	55.10	3.54	1.12
Ab WIP (HRS)	14.84	14.05	14.21	14.59	13.83	14.48	14.45	13.87	14.23	14.35	14.27	0.28	0.08
WC 410 Utilization %	18.88	18.43	17.89	17.97	18.64	19.20	18.28	18.88	18.88	20.27	18.88	0.69	0.22
WC 460 Utilization %	23.88	25.07	24.39	21.25	24.53	23.04	24.24	24.24	24.95	23.71	23.84	1.08	0.33
WC 414 Utilization %	7.53	8.02	7.78	6.98	7.61	7.18	7.91	7.88	7.71	7.88	7.88	0.36	0.11
Num AC AWP (UNITS)	50.28	58.24	49.82	48.18	49.54	47.69	50.90	52.20	53.86	58.65	51.31	3.44	1.09
AC Eng processed (UNITS)	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Engns repaired (UNITS)	308.00	302.00	298.00	295.00	293.00	282.00	284.00	299.00	299.00	301.00	291.80	11.98	3.78
Fens repaired (UNITS)	298.00	295.00	298.00	297.00	295.00	287.00	284.00	299.00	299.00	294.00	284.20	12.85	4.00
Hpts repaired (UNITS)	118.00	122.00	107.00	101.00	117.00	124.00	124.00	105.00	132.00	129.00	117.40	10.57	3.94
Lpts repaired (UNITS)	197.00	198.00	190.00	115.00	127.00	110.00	125.00	133.00	129.00	129.00	128.20	8.38	2.85
Hpcs repaired (UNITS)	134.00	148.00	141.00	127.00	143.00	112.00	118.00	142.00	135.00	138.00	135.10	13.07	4.13
Chbs repaired (UNITS)	45.00	57.00	59.00	58.00	43.00	49.00	52.00	59.00	55.00	59.00	53.30	6.83	1.84
Abcs repaired (UNITS)	108.00	111.00	94.00	93.00	90.00	81.00	107.00	108.00	113.00	113.00	100.80	10.88	3.44
BomEngines (UNITS)	182.00	188.00	186.00	170.00	184.00	180.00	185.00	188.00	209.00	182.00	188.00	9.55	3.02
BomFens (UNITS)	10.00	8.00	10.00	8.00	8.00	10.00	5.00	8.00	8.00	5.00	7.30	2.45	0.78
BomHpts (UNITS)	20.00	28.00	16.00	15.00	16.00	8.00	14.00	14.00	12.00	25.00	18.90	5.65	1.79
BomHpts (UNITS)	59.00	67.00	50.00	50.00	64.00	53.00	54.00	55.00	65.00	50.00	58.70	6.60	2.09
BomLpts (UNITS)	13.00	8.00	13.00	5.00	9.00	11.00	4.00	6.00	9.00	2.00	8.00	3.74	1.18
BomHpcs (UNITS)	15.00	15.00	21.00	14.00	14.00	14.00	9.00	19.00	19.00	16.00	14.90	3.88	1.05
BomChbs (UNITS)	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	8.00	0.90	0.92	0.29
BomAbs (UNITS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SUMMARY OF RESULTS FOR CURRENT AND LEMORE WITH LOG NORMAL DISTRIBUTION
 REPLICATION #

REPLICATION #	1	2	3	4	5	6	7	8	9	10			
Avg EngSpore use (UNITS)	2.38	3.16	2.62	1.82	2.47	3.25	2.54	2.45	3.34	3.76	2.75	0.82	0.20
Avg FerSpore use (UNITS)	10.11	10.47	10.85	9.40	11.10	10.32	11.24	10.46	11.20	11.19	10.91	0.59	0.19
Avg HpcSpore use (UNITS)	4.28	4.76	5.76	5.00	3.86	4.47	5.05	5.44	5.27	5.83	4.95	0.80	0.19
Avg HptSpore use (UNITS)	5.01	5.47	4.76	4.25	5.09	4.26	4.87	5.00	5.10	4.51	4.93	0.96	0.12
Avg LptSpore use (UNITS)	2.23	2.46	2.23	1.94	2.26	1.94	1.81	2.20	2.17	2.39	2.17	0.21	0.07
Avg OribSpore use (UNITS)	7.65	8.06	7.46	7.35	6.97	6.91	7.86	7.96	8.34	8.46	7.97	0.80	0.19
Avg AobSpore use (UNITS)	2.57	2.75	2.66	2.23	2.85	2.54	2.69	2.78	2.91	2.66	2.93	0.19	0.06

SUMMARY OF RESULTS FOR CURRENT AND LEMOORE WITH TRIANGULAR DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	4.11	4.16	4.18	4.15	4.75	4.28	4.19	4.12	11.90	4.41	5.00	2.39	0.74
ACTAT (HRS)	10.32	10.39	10.41	10.36	10.97	10.43	10.44	10.35	17.85	10.88	11.21	2.34	0.74
Eng AWP (HRS)	80.36	106.30	78.97	41.44	79.27	58.60	81.34	78.98	190.50	97.78	86.65	23.55	7.46
Eng TAT (HRS)	111.30	140.43	109.43	72.23	110.23	126.44	113.50	104.48	189.50	130.70	117.72	23.38	7.90
Fan TAT (HRS)	920.55	990.77	942.06	922.24	915.59	990.82	994.29	981.40	981.32	920.17	927.92	8.02	2.54
Hpc TAT (HRS)	841.59	860.59	878.85	848.22	862.81	895.54	864.39	849.97	894.07	875.82	863.55	16.22	4.81
Hpt TAT (HRS)	237.54	241.78	240.74	235.94	242.13	241.28	243.82	233.56	238.78	237.30	236.28	3.20	1.01
Lpt TAT (HRS)	183.97	190.23	177.73	182.96	185.81	191.85	191.34	185.94	186.82	181.54	186.72	6.10	1.86
Onb TAT (HRS)	778.16	768.63	768.81	782.01	769.58	764.89	768.01	768.35	769.10	767.12	765.27	8.25	2.61
As TAT (HRS)	158.63	198.37	161.32	151.31	174.74	171.70	176.31	164.98	180.08	168.90	172.09	15.92	5.03
Fan AWP (HRS)	849.00	867.80	867.04	862.24	859.20	890.26	867.66	858.78	859.64	848.90	854.55	8.41	2.65
Hpc AWP (HRS)	772.78	784.36	810.36	764.54	776.32	766.16	790.99	778.06	767.13	765.26	762.69	13.43	4.25
Hpt AWP (HRS)	181.71	181.55	183.49	180.29	188.98	182.52	185.34	178.75	180.99	179.47	181.78	2.08	0.65
Lpt AWP (HRS)	77.27	79.08	79.25	79.75	79.28	79.82	78.80	79.00	78.46	78.46	78.42	0.94	0.30
Onb AWP (HRS)	732.36	700.22	718.36	721.72	730.41	720.47	725.08	712.36	717.81	716.61	719.54	9.17	2.90
As AWP (HRS)	108.86	103.91	105.17	108.78	101.74	102.21	104.47	102.70	103.21	101.88	103.28	1.20	0.36
Fan WIP (HRS)	51.42	51.51	48.94	49.77	53.20	48.76	51.77	51.23	52.29	51.81	51.07	1.46	0.46
Hpc WIP (HRS)	43.43	44.02	42.35	39.98	40.47	41.53	45.99	44.05	43.51	40.01	42.47	1.90	0.60
Hpt WIP (HRS)	33.65	38.37	33.85	39.65	39.09	39.98	34.83	32.09	32.64	32.08	33.96	0.78	0.25
Lpt WIP (HRS)	83.18	88.08	79.39	82.08	88.48	86.77	86.78	83.35	88.31	79.55	89.79	3.95	1.24
Onb WIP (HRS)	15.09	15.10	15.37	15.27	15.04	15.16	15.26	15.45	15.04	15.21	15.20	0.14	0.04
As WIP (HRS)	21.35	21.22	21.65	21.20	21.92	21.71	21.51	21.88	21.96	21.64	21.81	0.28	0.09
WC 41U Utilization %	28.61	28.79	28.69	28.57	28.47	28.22	28.07	28.69	27.83	28.22	28.20	1.07	0.34
WC 450 Utilization %	8.58	8.73	8.38	7.43	8.28	8.02	8.24	8.37	8.21	8.74	8.90	0.36	0.12
WC 414 Utilization %	67.88	72.55	63.72	68.31	65.61	63.25	66.92	66.57	65.28	67.88	66.77	4.28	1.35
Num AC AWP (UNITS)	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.25	0.01	0.03	0.08	0.02
AC Eng processed (UNITS)	303.00	302.00	290.00	284.00	298.00	282.00	294.00	299.00	299.00	301.00	291.60	12.28	3.89
Engines repaired (UNITS)	291.00	295.00	296.00	285.00	294.00	276.00	276.00	289.00	277.00	298.00	289.20	12.47	3.94
Fans repaired (UNITS)	116.00	126.00	114.00	98.00	112.00	109.00	121.00	101.00	123.00	130.00	114.90	10.80	3.41
Lpts repaired (UNITS)	128.00	126.00	120.00	93.00	124.00	118.00	115.00	117.00	111.00	188.00	118.50	11.54	3.65
Hpts repaired (UNITS)	128.00	142.00	129.00	119.00	135.00	129.00	120.00	144.00	117.00	184.00	129.70	6.98	2.83
Hpcs repaired (UNITS)	62.00	67.00	69.00	54.00	48.00	48.00	68.00	55.00	68.00	62.00	58.10	5.70	1.80
Onbs repaired (UNITS)	124.00	108.00	105.00	91.00	98.00	90.00	100.00	99.00	107.00	98.00	101.70	6.88	3.11
As repaired (UNITS)	204.00	206.00	213.00	185.00	186.00	186.00	188.00	196.00	199.00	195.00	193.50	15.78	4.98
BomEngines (UNITS)	11.00	11.00	10.00	8.00	10.00	6.00	6.00	7.00	7.00	19.00	6.70	2.71	0.86
BomFans (UNITS)	18.00	24.00	9.00	14.00	23.00	15.00	22.00	12.00	10.00	10.00	15.70	5.72	1.91
BomHpts (UNITS)	67.00	60.00	60.00	46.00	46.00	66.00	67.00	72.00	70.00	69.00	60.20	8.69	2.75
BomLpts (UNITS)	9.00	9.00	5.00	9.00	10.00	4.00	8.00	13.00	9.00	10.00	8.90	2.55	0.81
BomHpcs (UNITS)	21.00	21.00	19.00	19.00	22.00	14.00	21.00	24.00	18.00	22.00	19.90	3.05	0.95
BomOnbs (UNITS)	0.00	1.00	2.00	0.00	0.00	0.00	0.00	1.00	0.00	2.00	0.90	0.84	0.27
BomAsbs (UNITS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

SUMMARY OF RESULTS FOR CURRENT AIMD LEMOORE WITH TRIANGULAR DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Ang EngSpore use (UNITS)	9.87	4.84	3.72	2.25	3.88	3.88	3.88	3.88	6.00	4.42	3.88	0.78	0.26
Ang FarSpore use (UNITS)	11.50	11.01	10.86	9.42	10.82	10.28	11.86	10.44	9.98	11.24	10.87	0.84	0.20
Ang HpcSpore use (UNITS)	6.95	5.81	6.27	5.57	5.04	5.05	6.58	5.95	6.25	6.85	5.81	0.54	0.17
Ang HptSpore use (UNITS)	5.60	5.11	5.36	4.53	4.92	5.47	5.53	5.74	5.28	5.76	5.38	0.38	0.12
Ang LptSpore use (UNITS)	2.57	3.16	2.86	2.48	2.78	2.88	2.88	3.10	2.40	2.76	2.88	0.27	0.09
Ang CntSpore use (UNITS)	9.18	8.43	8.88	7.22	7.87	8.88	7.78	8.11	7.79	7.88	7.87	0.68	0.21
Ang AbsSpore use (UNITS)	3.27	3.88	3.88	2.37	3.25	3.25	3.22	3.14	3.08	3.88	3.20	0.94	0.11

SUMMARY OF RESULTS FOR EXPANDED AND CECIL FIELD WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	5.00	6.06	4.71	4.19	4.19	10.90	5.92	9.71	4.84	24.90	6.00	0.21	1.96
AC TAT (HRS)	10.87	11.87	10.97	9.96	9.84	18.67	11.76	15.36	10.58	30.12	13.74	0.20	1.96
Eng AWP (HRS)	149.46	150.96	149.62	150.11	115.26	181.90	186.94	186.76	140.17	179.81	144.09	22.02	6.96
Eng TAT (HRS)	189.84	174.99	181.01	151.54	159.44	205.54	185.94	211.50	183.15	228.39	187.86	22.99	7.24
Fin TAT (HRS)	710.36	727.66	727.06	730.66	728.87	709.52	719.28	725.97	719.81	749.53	724.85	11.46	3.52
Hpc AWP (HRS)	682.86	709.96	719.03	728.47	704.96	724.46	695.28	688.24	685.76	702.82	708.16	13.95	4.41
Hpc TAT (HRS)	612.71	619.32	611.50	615.42	604.96	608.74	616.82	620.98	616.42	617.07	616.79	9.98	2.89
Lpt TAT (HRS)	482.82	495.87	490.67	487.55	478.76	498.53	499.29	481.22	478.90	484.90	486.76	6.98	2.16
Ab TAT (HRS)	1467.20	1459.20	1474.00	1421.90	1474.10	1618.40	1494.20	1444.80	1414.80	1479.40	1462.68	32.95	10.29
Ab TAT (HRS)	371.42	398.99	384.96	367.96	365.43	374.25	390.95	371.90	375.40	372.31	368.29	5.96	1.85
Fin AWP (HRS)	669.09	677.36	679.56	680.49	674.48	669.25	668.35	679.40	669.55	665.04	672.96	11.32	3.96
Hpc AWP (HRS)	615.86	643.24	641.61	632.85	639.18	632.16	624.98	607.34	616.37	610.48	628.36	15.80	4.98
Hpc TAT (HRS)	563.69	571.37	566.21	568.54	567.86	568.66	565.27	571.25	569.25	565.22	568.71	8.04	2.54
Lpt AWP (HRS)	434.83	442.95	441.68	437.37	428.99	443.73	435.96	427.12	425.86	428.84	434.67	6.74	2.13
Ab AWP (HRS)	1426.50	1399.00	1426.50	1389.50	1452.30	1469.90	1446.90	1377.90	1387.21	1395.00	1409.08	32.14	10.16
Ab AWP (HRS)	331.86	329.77	325.69	318.30	326.09	335.02	322.98	332.18	338.21	332.41	328.99	5.74	1.82
Fin WIP (HRS)	23.42	21.71	20.93	22.96	25.36	22.54	24.36	21.42	22.25	24.57	22.95	1.46	0.46
Hpc WIP (HRS)	45.36	32.45	48.94	44.06	37.02	53.30	37.73	47.35	43.80	40.11	42.81	6.08	1.92
Lpt WIP (HRS)	18.76	19.50	17.68	18.30	18.76	18.76	18.26	18.04	17.57	18.76	18.38	0.45	0.14
Ab WIP (HRS)	18.20	22.04	19.49	21.06	20.92	19.70	21.29	20.54	19.57	19.80	20.27	1.10	0.35
Ab WIP (HRS)	12.18	12.01	12.25	12.34	12.35	12.00	12.95	12.26	12.02	11.82	12.16	0.18	0.06
Ab WIP (HRS)	11.70	11.53	11.70	11.94	11.87	11.90	11.76	11.75	11.79	11.76	11.77	0.12	0.04
WC 411 Utilization %	64.36	49.86	49.86	49.86	47.30	49.86	48.16	48.17	50.26	53.00	49.77	2.25	0.71
WC 420 Utilization %	5.44	5.02	4.85	4.87	4.78	4.81	4.71	5.08	4.93	5.29	4.97	0.23	0.07
WC 414 Utilization %	68.66	60.72	63.76	62.99	60.76	61.66	65.34	63.64	68.08	61.74	65.52	3.96	1.25
WC 413 Utilization %	25.08	23.78	23.45	25.76	23.31	24.18	23.90	22.50	25.03	25.42	24.28	1.05	0.39
WC 415 Utilization %	0.76	0.79	0.83	1.01	0.76	0.76	0.86	0.86	0.86	0.85	0.81	0.15	0.05
Num AWP (UNITS)	0.05	0.06	0.08	0.08	0.01	0.24	0.08	0.19	0.04	0.76	0.16	0.23	0.07
AC Er. J processed (UNITS)	325.00	305.00	295.00	304.00	282.00	301.00	300.00	290.00	300.00	323.00	302.80	1.82	4.40
Engines repaired (UNITS)	320.00	292.00	295.00	281.00	275.00	283.00	279.00	287.00	291.00	309.00	290.20	14.05	4.44
Fins repaired (UNITS)	127.00	125.00	104.00	108.00	114.00	114.00	127.00	117.00	127.00	121.00	118.40	8.98	2.84
Hpts repaired (UNITS)	176.00	165.00	176.00	168.00	164.00	172.00	178.00	165.00	172.00	188.00	169.00	8.87	2.80
Lpts repaired (UNITS)	189.00	180.00	181.00	185.00	128.00	147.00	136.00	131.00	160.00	149.00	146.90	12.18	3.85
Hpcs repaired (UNITS)	104.00	108.00	100.00	111.00	108.00	123.00	119.00	108.00	124.00	116.00	110.60	9.20	2.91
Orbs repaired (UNITS)	81.00	79.00	85.00	85.00	75.00	76.00	70.00	86.00	74.00	88.00	77.80	7.93	2.32
Ab repaired (UNITS)	188.00	180.00	176.00	189.00	172.00	178.00	178.00	168.00	189.00	189.00	180.40	7.40	2.34
BomEngines (UNITS)	10.00	13.00	8.00	19.00	6.00	17.00	15.00	9.00	15.00	13.00	12.70	3.98	1.22
BomFins (UNITS)	14.00	11.00	9.00	8.00	13.00	12.00	9.00	6.00	10.00	7.00	9.90	2.90	0.82
BomHpts (UNITS)	10.00	10.00	8.00	8.00	5.00	4.00	9.00	9.00	7.00	4.00	7.20	2.95	0.74
BomLpts (UNITS)	7.00	7.00	2.00	3.00	6.00	4.00	6.00	3.00	7.00	3.00	4.80	1.99	0.63
BomHpcs (UNITS)	3.00	1.00	2.00	4.00	0.00	0.00	1.00	3.00	2.00	3.00	1.90	1.37	0.43
BomOrbs (UNITS)	13.00	7.00	6.00	6.00	2.00	3.00	6.00	5.00	4.00	7.00	6.10	3.07	0.97
BomAbs (UNITS)	1.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.40	0.52	0.16
Farebals (UNITS)	9.00	11.00	8.00	15.00	11.00	10.00	12.00	11.00	12.00	7.00	9.90	2.73	0.86
Hpcbals (UNITS)	8.00	9.00	5.00	9.00	4.00	7.00	8.00	5.00	12.00	9.00	6.90	2.69	0.85
Lptbals (UNITS)	2.00	2.00	7.00	4.00	1.00	4.00	3.00	3.00	2.00	2.00	3.00	1.70	0.54
Hpcbals (UNITS)	7.00	9.00	9.00	9.00	10.00	6.00	4.00	5.00	14.00	10.00	8.90	2.91	0.92

SUMMARY OF RESULTS FOR EXPANDED AINO CECIL FIELD WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Ang EngSpore use (UNITS)	7.06	6.98	6.14	6.27	6.06	6.99	6.96	6.94	6.41	7.40	6.28	0.74	0.24
Ang FerSpore use (UNITS)	10.24	9.76	8.96	9.90	9.09	8.97	9.99	9.96	9.96	9.92	9.96	0.92	0.19
Ang HpcSpore use (UNITS)	8.06	7.96	7.96	8.97	7.72	9.29	8.94	7.87	9.21	8.96	8.90	0.92	0.19
Ang HpcSpore use (UNITS)	10.66	10.26	10.41	10.47	10.92	10.96	10.96	9.96	10.40	10.96	10.46	0.96	0.10
Ang LptSpore use (UNITS)	8.47	7.86	8.44	7.11	6.77	7.96	7.96	6.70	8.96	7.76	7.66	0.96	0.21
Ang OncoSpore use (UNITS)	9.99	9.76	9.96	9.72	9.94	9.91	9.26	9.96	9.91	9.94	9.99	0.22	0.07
Ang AbsSpore use (UNITS)	9.26	6.76	6.90	6.02	6.92	6.94	6.96	6.96	6.96	6.96	6.90	1.06	0.34

SUMMARY OF RESULTS FOR EXPANDED AND LENOORE WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	3.75	3.66	3.77	3.77	3.81	3.90	3.84	3.92	3.84	3.76	3.82	0.06	0.02
AC TAT (HRS)	9.53	9.53	9.42	9.46	9.40	9.66	9.64	9.66	9.53	9.57	9.54	0.06	0.05
Eng AWP (HRS)	46.73	58.20	50.10	56.94	53.86	59.91	40.07	55.91	67.01	41.37	46.92	10.76	3.40
Eng TAT (HRS)	72.83	84.47	77.39	82.54	81.46	86.62	66.54	83.53	92.15	67.22	73.47	10.46	3.31
Fan TAT (HRS)	742.46	726.96	736.61	726.30	726.96	750.96	722.12	744.94	750.28	740.23	734.96	9.57	3.03
Hpc TAT (HRS)	666.91	675.76	680.82	679.96	682.51	699.02	683.74	673.99	678.16	642.11	672.90	13.05	4.13
Hpt TAT (HRS)	190.53	194.86	191.97	187.76	190.02	185.86	186.81	186.37	189.54	187.61	190.23	3.07	0.97
Lpt TAT (HRS)	145.77	136.16	152.08	144.49	148.32	155.85	150.70	161.25	146.96	146.84	146.98	7.92	2.32
Onb TAT (HRS)	606.47	614.95	600.42	600.53	600.83	622.65	613.80	616.94	606.32	623.91	610.18	10.42	3.29
Ab TAT (HRS)	132.01	139.25	134.66	130.65	139.66	155.08	137.33	159.35	100.95	158.16	142.12	11.70	3.70
Fan AWP (HRS)	679.27	694.09	672.63	683.79	685.03	691.57	664.36	683.68	686.37	678.96	672.52	10.46	3.31
Hpc AWP (HRS)	609.54	615.00	623.08	634.48	629.19	600.35	630.22	612.34	616.13	583.33	615.36	15.36	4.87
Hpt AWP (HRS)	142.99	144.40	140.48	142.15	142.81	144.57	141.47	140.36	143.19	142.40	143.06	1.79	0.55
Lpt AWP (HRS)	59.40	61.06	61.62	61.96	59.66	61.37	59.49	62.34	61.80	61.45	61.01	1.09	0.34
Onb AWP (HRS)	696.70	676.95	657.28	673.74	651.98	670.28	657.58	699.41	653.97	690.36	669.66	9.95	3.05
Ab AWP (HRS)	80.25	81.42	80.62	80.66	81.17	82.15	83.21	83.71	79.95	81.29	81.64	1.58	0.46
Fan WIP (HRS)	44.81	49.29	46.15	44.18	42.49	49.09	49.67	41.96	42.95	43.16	43.13	1.51	0.46
Hpc WIP (HRS)	35.55	35.22	35.10	29.27	32.10	31.95	30.72	35.14	30.24	34.34	32.75	2.26	0.72
Hpt WIP (HRS)	26.87	30.66	26.16	26.23	26.17	28.47	24.72	25.80	26.00	25.56	26.64	1.70	0.54
Lpt WIP (HRS)	65.54	57.10	69.89	68.96	65.74	70.98	77.75	76.08	64.23	64.02	67.52	6.21	1.95
Onb WIP (HRS)	17.89	17.67	17.86	17.95	17.91	18.27	17.69	17.89	18.16	18.04	17.83	0.42	0.13
Ab WIP (HRS)	23.89	23.50	22.00	24.46	23.83	23.08	22.75	23.13	23.77	22.04	23.22	0.79	0.25
WC 41U Utilization %	24.56	24.19	25.21	22.16	24.98	23.81	23.47	25.20	22.78	24.47	24.06	1.04	0.33
WC 450 Utilization %	7.96	8.11	7.95	6.87	7.57	7.79	7.54	7.81	7.53	7.96	7.70	0.35	0.11
WC 414 Utilization %	62.18	64.14	65.11	62.96	61.07	66.42	63.33	67.35	61.08	61.98	61.98	3.96	1.22
WC 415 Utilization %	1.84	1.34	1.11	1.47	1.53	1.26	1.19	1.36	1.31	1.29	1.37	0.21	0.07
Num AC AWP (UNITS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AC Eng processed (UNITS)	303.00	302.00	299.00	294.00	298.00	282.00	294.00	299.00	299.00	301.00	291.90	12.28	3.68
Engines repaired (UNITS)	259.00	294.00	282.00	295.00	282.00	299.00	281.00	291.00	281.00	294.00	289.30	12.98	3.97
Fans repaired (UNITS)	125.00	143.00	113.00	115.00	121.00	119.00	121.00	141.00	137.00	126.00	126.10	10.97	3.37
Hpts repaired (UNITS)	143.00	147.00	164.00	145.00	167.00	141.00	160.00	159.00	147.00	168.00	150.90	7.54	2.36
Lpts repaired (UNITS)	133.00	137.00	150.00	107.00	134.00	127.00	136.00	137.00	127.00	145.00	135.90	11.65	3.68
Hpcs repaired (UNITS)	76.00	70.00	2.00	69.00	67.00	76.00	66.00	71.00	76.00	75.00	69.70	5.76	1.82
Onbs repaired (UNITS)	108.00	125.00	116.00	97.00	95.00	102.00	109.00	105.00	108.00	92.00	105.30	9.69	3.13
Abx repaired (UNITS)	186.00	212.00	196.00	179.00	208.00	174.00	186.00	207.00	197.00	168.00	192.80	13.15	4.16
BomEngines (UNITS)	8.00	12.00	5.00	11.00	11.00	10.00	5.00	9.00	7.00	7.00	8.50	2.51	0.79
BomFans (UNITS)	7.00	10.00	8.00	8.00	9.00	6.00	5.00	3.00	6.00	7.00	6.90	2.02	0.64
BomHpts (UNITS)	36.00	40.00	34.00	23.00	27.00	24.00	30.00	22.00	30.00	36.00	30.10	6.10	1.98
BomLpts (UNITS)	5.00	8.00	3.00	4.00	1.00	3.00	3.00	6.00	5.00	4.00	4.20	1.98	0.61
BomHpcs (UNITS)	4.00	5.00	4.00	9.00	8.00	3.00	3.00	7.00	7.00	6.00	5.90	2.26	0.71
BomOnbs (UNITS)	0.00	1.00	0.00	1.00	1.00	0.00	0.00	1.00	2.00	1.00	0.70	0.87	0.21
BomAbx (UNITS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FanAbx (UNITS)	10.00	10.00	8.00	11.00	11.00	6.00	6.00	9.00	12.00	11.00	9.40	2.12	0.67
HptAbx (UNITS)	26.00	17.00	19.00	26.00	34.00	19.00	22.00	26.00	24.00	21.00	23.40	5.17	1.66
LptAbx (UNITS)	8.00	1.00	1.00	0.00	1.00	1.00	5.00	1.00	5.00	2.00	2.50	2.59	0.82
HpcAbx (UNITS)	16.00	16.00	11.00	12.00	11.00	13.00	9.00	12.00	9.00	11.00	11.90	2.28	0.72

SUMMARY OF RESULTS FOR EXPANDED AINO LEMOORE WITH LOG NORMAL DISTRIBUTION

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean	
Avg EngSpore use (UNITS)	2.53	2.96	2.88	1.96	2.12	2.24	2.10	2.82	3.06	2.30	2.30	2.47	0.36	0.12
Avg FarSpore use (UNITS)	6.86	10.88	9.24	8.82	10.17	9.76	8.94	10.74	10.07	9.96	9.96	9.76	0.86	0.21
Avg HpdSpore use (UNITS)	5.87	5.27	5.10	4.40	5.46	5.84	4.99	5.78	5.67	5.43	5.43	5.34	0.42	0.13
Avg HptSpore use (UNITS)	4.24	4.37	4.47	3.67	4.12	3.78	3.97	3.97	4.06	4.28	4.28	4.06	0.26	0.08
Avg LptSpore use (UNITS)	2.11	2.06	2.40	1.96	1.98	2.12	2.26	2.40	1.99	2.28	2.28	2.13	0.22	0.07
Avg CntSpore use (UNITS)	7.20	7.64	7.63	6.37	6.07	7.12	7.11	7.48	6.96	6.40	6.40	6.96	0.53	0.17
Avg ADSpore use (UNITS)	2.46	2.90	2.69	2.24	2.77	2.67	2.49	3.23	2.86	2.68	2.68	2.67	0.27	0.08

SUMMARY OF RESULTS FOR EXPANDED AND CECIL FIELD WITH LOG NORMAL DISTRIBUTION (400 ENGINES PER YEAR)

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	142.52	17.01	19.77	37.03	61.53	99.28	118.31	74.25	81.56	27.95	69.39	42.16	19.39
AC TAT (HRS)	148.26	22.77	26.54	42.71	67.16	45.04	218.06	79.95	87.23	38.09	82.04	42.14	19.39
Eng AWP (HRS)	321.17	162.26	205.35	218.23	246.49	222.32	288.16	265.17	221.20	195.13	232.04	47.31	14.86
Eng TAT (HRS)	397.49	198.95	251.19	264.00	297.94	278.46	335.65	312.99	270.47	246.02	269.85	62.51	16.61
Fan AWP (HRS)	731.87	724.19	798.08	737.85	727.86	728.51	732.04	729.40	723.06	725.95	726.71	5.19	1.84
Hpc TAT (HRS)	898.73	798.76	798.52	715.20	816.28	724.24	797.39	722.27	774.08	747.31	767.14	48.39	15.30
Hpc TAT (HRS)	834.16	821.98	828.28	864.95	894.58	815.08	862.79	892.71	805.38	828.19	828.28	9.86	3.05
Lpt TAT (HRS)	497.87	483.03	474.59	478.58	504.82	505.99	499.65	503.46	487.46	495.42	492.05	11.67	3.86
Orb TAT (HRS)	1916.20	1608.00	1468.90	1467.30	1572.50	1468.00	1608.40	1607.10	1608.90	1642.90	1582.28	138.54	44.13
Ab TAT (HRS)	370.15	374.83	371.19	378.42	370.81	379.82	374.99	375.01	368.96	365.90	371.70	3.39	1.05
Fan AWP (HRS)	679.65	698.21	684.54	689.97	678.95	672.88	674.90	673.92	670.35	688.55	674.51	6.96	1.86
Hpc AWP (HRS)	628.07	645.73	642.48	638.41	632.05	607.86	628.70	633.53	659.47	638.84	635.58	18.55	4.28
Hpc AWP (HRS)	576.99	598.25	577.45	582.99	578.99	599.08	598.36	579.08	548.75	576.51	571.69	10.00	3.95
Lpt AWP (HRS)	424.99	424.34	421.01	420.90	431.97	435.08	428.81	439.94	429.28	426.13	427.98	6.14	1.94
Orb AWP (HRS)	1409.10	1445.90	1398.10	1404.50	1382.90	1385.90	1378.30	1423.90	1427.90	1435.90	1408.32	32.15	10.17
Ab AWP (HRS)	326.95	334.58	328.40	331.13	329.24	331.05	332.50	331.22	325.99	323.08	329.48	8.42	1.08
Fan WIP (HRS)	22.87	23.24	23.28	23.32	20.90	20.99	22.22	21.98	21.25	25.72	22.56	1.47	0.46
Hpc WIP (HRS)	46.57	48.90	43.35	37.94	60.76	41.46	48.88	41.72	51.14	47.20	46.39	6.46	2.04
Lpt WIP (HRS)	18.16	18.21	18.26	18.50	18.53	18.13	18.04	18.81	19.22	18.22	18.51	0.42	0.13
Orb WIP (HRS)	19.38	19.89	18.95	20.73	19.50	20.75	22.15	20.94	19.92	19.49	20.06	1.06	0.39
Ab WIP (HRS)	12.11	11.98	12.28	12.16	12.15	12.10	12.09	12.06	11.92	11.98	12.07	0.12	0.04
WC 411 Utilization %	96.07	62.87	60.98	64.98	62.73	66.85	68.58	72.02	68.53	65.95	65.45	8.23	1.02
WC 460 Utilization %	6.76	6.25	6.12	6.40	6.22	6.65	6.91	7.37	6.49	6.76	6.90	0.36	0.12
WC 414 Utilization %	78.52	71.84	64.39	69.17	72.48	78.48	78.48	78.01	73.15	71.98	73.19	4.90	1.45
WC 415 Utilization %	32.55	29.22	35.30	32.43	32.16	39.05	32.69	33.39	29.91	29.55	31.73	1.75	0.55
WC 416 Utilization %	1.38	1.16	0.98	0.98	0.99	1.13	0.99	1.20	1.02	0.81	1.01	0.20	0.08
Num AC AWP (UNITS)	6.40	0.57	0.66	1.50	2.53	1.86	6.45	9.26	1.24	1.08	2.43	2.02	0.84
AC Eng processed (UNITS)	404.00	378.00	384.00	368.00	364.00	369.00	418.00	440.00	390.00	398.00	398.70	21.32	6.74
Engines repaired (UNITS)	383.00	364.00	357.00	379.00	364.00	369.00	385.00	424.00	374.00	383.00	381.10	19.18	6.07
Fans repaired (UNITS)	152.00	132.00	135.00	157.00	152.00	161.00	180.00	191.00	189.00	141.00	154.00	16.50	5.22
Hpc repaired (UNITS)	214.00	201.00	199.00	220.00	214.00	215.00	287.00	241.00	209.00	218.00	219.90	18.76	4.95
Lpts repaired (UNITS)	195.00	199.00	181.00	197.00	190.00	201.00	197.00	198.00	196.00	185.00	192.10	6.45	2.04
Hpcs repaired (UNITS)	178.00	163.00	128.00	127.00	118.00	193.00	157.00	194.00	194.00	137.00	145.00	19.19	6.07
Orbs repaired (UNITS)	98.00	73.00	98.00	107.00	101.00	107.00	94.00	123.00	107.00	98.00	100.50	12.74	4.03
Ab repaired (UNITS)	298.00	215.00	250.00	241.00	242.00	247.00	244.00	244.00	215.00	224.00	238.10	19.09	4.14
BomEngines (UNITS)	13.00	11.00	7.00	17.00	19.00	14.00	28.00	15.00	16.00	14.00	14.90	4.36	1.38
BomFins (UNITS)	9.00	18.00	18.00	19.00	12.00	28.00	20.00	18.00	10.00	8.00	15.00	6.28	1.85
BomHps (UNITS)	14.00	17.00	8.00	8.00	13.00	12.00	9.00	10.00	11.00	12.00	11.40	2.94	0.90
BomLpts (UNITS)	10.00	7.00	3.00	9.00	2.00	6.00	9.00	7.00	8.00	7.00	6.80	2.53	0.80
BomHpcs (UNITS)	3.00	2.00	1.00	4.00	5.00	6.00	7.00	6.00	8.00	4.00	4.90	2.22	0.70
BomOrbs (UNITS)	6.00	8.00	11.00	10.00	6.00	8.00	10.00	11.00	8.00	7.00	8.50	1.90	0.60
BomAbs (UNITS)	0.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	4.00	1.00	1.15	0.37
FanOrbs (UNITS)	11.00	13.00	5.00	10.00	14.00	18.00	20.00	19.00	7.00	11.00	12.80	5.09	1.69
HpcOrbs (UNITS)	18.00	15.00	7.00	10.00	9.00	11.00	10.00	11.00	10.00	10.00	11.10	3.14	0.98
LptOrbs (UNITS)	4.00	4.00	3.00	5.00	1.00	5.00	1.00	5.00	8.00	4.00	4.00	2.05	0.85
HpcOrbs (UNITS)	13.00	9.00	7.00	7.00	8.00	8.00	6.00	8.00	9.00	8.00	8.10	2.02	0.84

SUMMARY OF RESULTS FOR EXPANDED AND CECIL FIELD WITH LOG NORMAL DISTRIBUTION (400 ENGINES PER YEAR)

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Ang EngSpore use (UNITS)	10.86	7.85	9.48	10.30	10.31	10.58	10.81	11.24	10.57	9.89	10.19	0.96	0.30
Ang FanSpore use (UNITS)	10.74	10.22	10.83	10.83	11.09	11.32	11.09	11.30	10.76	10.85	10.85	0.95	0.11
Ang HpcSpore use (UNITS)	11.70	10.79	9.85	9.85	9.80	10.57	10.75	11.23	10.82	10.02	10.51	0.88	0.21
Ang HpcSpore use (UNITS)	11.30	11.08	11.08	11.88	11.84	11.61	11.46	11.91	11.71	11.89	11.81	0.16	0.05
Ang LpcSpore use (UNITS)	9.78	9.84	8.78	9.87	9.45	10.24	9.85	10.08	9.55	9.39	9.86	0.41	0.18
Ang CmbSpore use (UNITS)	9.82	9.86	9.89	10.00	10.00	10.00	10.00	10.00	10.00	9.99	9.98	0.05	0.02
Ang ACSpore use (UNITS)	8.51	6.73	6.70	6.80	6.86	6.84	6.70	6.89	6.55	6.59	6.65	0.10	0.08

SUMMARY OF RESULTS FOR EXPANDED AIMD LEMOORE WITH LOG NORMAL DISTRIBUTION (400 ENGINES PER YEAR)

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Time AC AWP (HRS)	108.68	8.82	12.87	27.95	41.38	187.87	108.79	114.64	183.98	82.71	82.80	58.40	18.47
AC TAT (HRS)	114.36	14.71	18.89	33.58	47.17	144.00	114.22	120.82	180.97	86.48	86.56	58.90	18.46
Eng AWP (HRS)	264.68	95.94	107.95	158.76	188.26	290.90	265.05	264.98	328.17	224.86	214.16	81.45	25.76
Eng TAT (HRS)	282.80	128.00	194.81	165.81	188.76	317.87	289.90	291.94	365.44	251.81	241.04	81.90	25.90
Fen AWP (HRS)	748.18	729.96	731.78	729.74	754.75	743.81	748.20	761.09	742.23	741.81	740.91	9.79	3.10
Fen TAT (HRS)	764.61	664.81	665.86	672.16	698.63	713.82	718.98	728.82	698.10	719.90	708.86	28.83	9.12
Hpr AWP (HRS)	200.32	180.36	200.70	198.57	184.51	195.11	199.94	205.98	195.90	198.98	197.81	4.19	1.38
Hpr TAT (HRS)	198.08	161.57	169.84	168.92	161.96	180.12	178.18	185.24	164.90	180.82	172.26	13.86	4.36
Crnb AWP (HRS)	782.81	629.34	644.88	641.45	644.47	788.82	698.74	783.75	681.25	690.57	678.06	44.98	14.18
Ab TAT (HRS)	491.82	217.71	282.97	268.77	310.86	699.96	468.82	474.50	619.47	419.90	405.46	141.80	44.84
Fen AWP (HRS)	677.97	698.12	694.82	698.75	698.57	678.94	698.77	698.00	678.18	674.11	674.68	9.80	3.04
Hpc AWP (HRS)	605.97	615.82	621.09	608.18	620.23	692.86	610.82	608.04	600.54	612.98	609.64	8.82	2.79
Hpr AWP (HRS)	144.16	143.96	145.10	142.81	144.82	143.86	144.48	144.48	143.81	141.41	143.72	1.10	0.35
Lpr AWP (HRS)	80.70	60.86	61.09	61.07	60.86	69.41	69.84	61.13	60.86	60.81	60.49	0.82	0.20
Crnb AWP (HRS)	590.94	598.82	590.31	594.46	598.81	598.59	599.80	590.20	592.94	597.79	598.82	9.90	3.19
Ab AWP (HRS)	80.76	83.95	80.79	83.82	81.74	82.85	82.84	82.76	81.23	81.95	82.16	1.02	0.32
Fen WIP (HRS)	48.28	45.74	49.14	48.83	48.53	41.85	42.81	41.91	44.35	43.24	43.46	1.35	0.48
Hpc WIP (HRS)	38.30	38.16	31.85	27.28	32.77	36.76	32.84	35.02	34.20	31.98	33.16	3.11	0.98
Hpr WIP (HRS)	25.95	28.16	29.02	27.00	25.82	24.79	27.02	26.86	27.87	26.59	28.41	1.82	0.51
Lpr WIP (HRS)	78.08	78.73	76.94	84.12	72.86	83.26	78.84	78.87	68.94	81.91	76.79	6.80	1.99
Crnb WIP (HRS)	18.01	17.79	17.63	18.11	18.21	17.49	17.68	17.69	17.91	18.01	17.84	0.24	0.06
Ab WIP (HRS)	23.89	22.91	23.16	24.05	24.21	23.88	23.87	23.04	24.06	23.88	23.87	0.47	0.16
WC 41U Utilization %	32.84	30.87	30.21	32.45	31.40	32.08	34.08	34.29	34.38	33.48	32.56	1.44	0.46
WC 46U Utilization %	10.88	9.76	9.80	10.36	10.08	10.37	10.34	10.82	11.90	10.18	10.37	0.82	0.16
WC 414 Utilization %	81.89	82.21	82.78	85.44	85.29	82.44	84.82	82.71	86.48	81.10	88.52	4.68	1.45
WC 418 Utilization %	1.88	1.90	1.44	1.88	2.08	2.18	1.78	2.23	1.80	1.82	1.86	0.25	0.08
Num AC AWP (UNITS)	4.84	0.22	0.38	1.08	1.84	6.28	5.85	6.28	6.80	5.85	5.86	2.88	0.88
AC Eng processed (UNITS)	404.00	377.00	388.00	387.00	388.00	408.00	388.00	412.00	488.00	384.00	388.70	19.47	6.18
Engines repaired (UNITS)	398.00	390.00	358.00	384.00	376.00	398.00	395.00	400.00	427.00	381.00	384.80	19.70	6.28
Fens repaired (UNITS)	185.00	188.00	182.00	184.00	176.00	188.00	188.00	187.00	181.00	177.00	176.50	11.10	3.51
Hprs repaired (UNITS)	208.00	204.00	178.00	215.00	224.00	225.00	238.00	240.00	218.00	229.00	217.30	17.84	5.58
Lprs repaired (UNITS)	184.00	178.00	186.00	188.00	181.00	181.00	200.00	185.00	178.00	184.00	180.20	11.86	3.70
Hpcs repaired (UNITS)	87.00	87.00	101.00	80.00	92.00	85.00	85.00	95.00	90.00	77.00	87.90	7.02	2.22
Crnbs repaired (UNITS)	180.00	128.00	122.00	124.00	184.00	148.00	180.00	189.00	183.00	128.00	188.30	8.82	2.72
Ab repaired (UNITS)	282.00	246.00	270.00	285.00	277.00	280.00	288.00	281.00	320.00	289.00	278.80	19.90	6.29
BomEngines (UNITS)	11.00	18.00	12.00	11.00	10.00	12.00	8.00	12.00	16.00	9.00	11.40	2.22	0.70
BomFens (UNITS)	4.00	8.00	3.00	9.00	6.00	13.00	14.00	6.00	9.00	9.00	8.10	5.54	1.12
BomHprs (UNITS)	46.00	33.00	37.00	45.00	28.00	36.00	36.00	40.00	28.00	36.00	36.70	5.88	1.84
BomLprs (UNITS)	5.00	4.00	2.00	7.00	11.00	2.00	4.00	6.00	6.00	3.00	5.00	2.71	0.86
BomHpcs (UNITS)	11.00	7.00	4.00	9.00	8.00	7.00	7.00	7.00	8.00	10.00	7.80	2.81	0.84
BomCrnbs (UNITS)	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.20	0.42	0.18
BomAbcs (UNITS)	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.32	0.10
FenAbcs (UNITS)	16.00	14.00	15.00	9.00	16.00	13.00	15.00	19.00	8.00	16.00	14.00	8.80	1.04
HprAbcs (UNITS)	28.00	37.00	28.00	38.00	32.00	30.00	35.00	32.00	37.00	36.00	32.50	3.78	1.19
LprAbcs (UNITS)	2.00	2.00	2.00	5.00	6.00	4.00	0.00	2.00	1.00	4.00	2.80	1.87	0.59
HpcAbcs (UNITS)	15.00	18.00	11.00	12.00	20.00	20.00	14.00	21.00	17.00	14.00	16.20	3.82	1.11

SUMMARY OF RESULTS FOR EXPANDED AIND LEMOORE WITH LOG NORMAL DISTRIBUTION (400 ENGINES PER YEAR)

REPLICATION #	1	2	3	4	5	6	7	8	9	10	Average	Std Dev	Std Err Mean
Avg EngSpare use (UNITS)	8.30	5.08	5.08	6.29	6.51	8.04	9.08	9.58	7.28	7.51	7.17	1.40	0.44
Avg FanSpare use (UNITS)	11.76	11.31	10.94	11.81	11.93	11.72	11.89	11.87	11.18	11.70	11.57	0.38	0.10
Avg HpcSpare use (UNITS)	7.36	6.90	7.78	6.02	7.28	6.55	6.91	7.94	6.76	6.41	6.98	0.81	0.19
Avg HptSpare use (UNITS)	5.93	5.17	5.18	6.10	6.44	5.98	6.10	6.59	5.45	6.12	5.81	0.47	0.15
Avg LptSpare use (UNITS)	3.85	3.08	2.82	3.19	2.98	3.52	3.75	3.72	2.87	3.59	3.38	0.40	0.18
Avg CrbSpare use (UNITS)	8.98	8.11	8.18	8.08	8.79	8.97	9.14	9.20	7.94	8.28	8.62	0.47	0.15
Avg AdbSpare use (UNITS)	5.90	4.46	4.34	4.97	4.98	5.72	5.91	5.76	5.05	5.37	5.24	0.58	0.18

APPENDIX F

Cost Benefit Analysis for Expanding Capabilities at AIMD Coal Field and Limestone
(Includes purchase of new spin balance and welding equipment and chiller augmentation)
Benefits

Year	FY-01	FY-02	FY-03	FY-04	FY-05	FY-06	FY-07	FY-08	FY-09	FY-10	Present Value
Mod/Less	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	\$6,124,770.54
PV Benefits	908,182.00	823,783.64	748,894.21	680,812.92	618,920.84	562,865.31	511,504.83	465,004.38	422,781.28	384,301.15	\$6,124,770.54
											PV Benefits = \$6,124,770.54

Selected AIMDs Costs:

Spin Balancing Machines	401,053.44										\$401,053.44
Welding Equipment	20,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	\$77,890.24
Maintenance Costs	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	\$10,188.54
Utilities	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	\$6,789.02
Set Up Costs	10,000.00										\$10,000.00

Personnel:

Spin Balance(2 ea.)	26,188.80	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	\$340,508.40
Welding(2 ea.)	26,188.80	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	50,377.60	\$340,508.40
Training	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	\$6,789.02
PV COSTS	538,300.84	108,885.36	94,426.76	85,841.82	78,087.84	70,948.48	64,484.08	58,880.88	53,300.88	48,455.36	\$1,188,307.06

PV Costs = \$1,188,307.06

PV Benefits - PV Costs

	570,883.36	719,916.27	654,468.45	594,971.50	540,883.00	491,711.82	447,010.74	405,379.40	368,480.37	335,945.76	\$4,931,463.48
											PV Savings = \$4,931,463.48

Cost Benefit Analysis for Expanding Capabilities of AIMD Coal Field and Limestone
(Includes utilization of existing spin balance machine; and training of Navy personnel)

Benefits	Year										Present Value
	FY-01	FY-02	FY-03	FY-04	FY-05	FY-06	FY-07	FY-08	FY-09	FY-10	
Module	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	908,182.00	96,124,770.54
PV Benefits	908,182.00	828,788.84	748,894.21	668,812.92	588,812.92	508,812.92	428,812.92	348,812.92	268,812.92	188,812.92	96,124,770.54
PV Benefits = 96,124,770.54											
Added AIMDs Costs:											
Holding Equipment	20,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	\$77,890.24
Maintenance Costs	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	\$10,198.54
Utilities	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00	\$8,789.02
Personnel:											
Training	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	10,000.00	\$87,890.24
PV COSTS	32,500.00	20,464.00	18,896.04	16,804.98	15,367.90	13,970.79	12,700.06	11,548.06	10,480.42	9,542.20	\$182,078.04
PV Costs = \$182,078.04											
PV Benefits - Costs	878,682.00	808,323.00	730,298.17	652,008.94	573,545.92	498,842.92	420,142.92	348,894.92	268,894.92	188,894.92	\$8,002,802.50
NPV Savings = \$8,002,802.50											

INITIAL DISTRIBUTION LIST

	No. Copies
1. Defense Technical Information Center Cameron Station Alexandria VA 22304-6145	2
2. Library, Code 052 Naval Postgraduate School Monterey CA 93943-5002	2
3. Defense Logistics Studies Information Center United States Army Logistics Management Center Fort Lee, VA 23801-6043	1
4. Commander, Naval Air Systems Command (AIR 43B) NAVAIRSYSCOM Headquarters CG-1 Room 300 Washington, D.C. 20361-4310	1
5. Commander Jeffery A. Warmington, Code AS/Wr Department of Administrative Sciences Naval Postgraduate School Monterey, CA 93943-5000	1
6. Professor Alan W. McMasters, Code AS/Mg Department of Administrative Sciences Naval Postgraduate School Monterey, CA 93943-5000	1
7. Professor Keebom Kang, Code AS/Kk Department of Administrative Sciences Naval Postgraduate School Monterey, CA 93943-5000	1
8. LCDR Stephen W. Bartlett 2662 Bottomridge Drive Orange Park, FL 32065-5730	2
9. LCDR Paul F. Braun 2125 Domingo Glen Escondido, CA 92026-0000	2
10. Commanding Officer Naval Air Station Lemoore, CA 93246-5001 ATTN:AIMD Officer (CDR Boyce)	1

- | | |
|--|---|
| 11. AIMD Officer | 1 |
| Aircraft Intermediate Maintenance Department | |
| Naval Air Station | |
| Cecil Field, FL 32215-0136 | |
| 12. Commanding Officer | 1 |
| Naval Aviation Depot | |
| Naval Air Station | |
| Jacksonville, FL 32212-0016 | |
| 13. Commander | 1 |
| Naval Air Force, U.S. Atlantic Fleet | |
| Code N422A | |
| 1279 Franklin Street | |
| Norfolk, VA 23511-2494 | |
| 14. Commander | 1 |
| Naval Air Force, U.S. Pacific Fleet | |
| Code 742 | |
| Box 357051 | |
| San Diego, CA 92135-7051 | |
| ATTN:LCDR Blunt | |